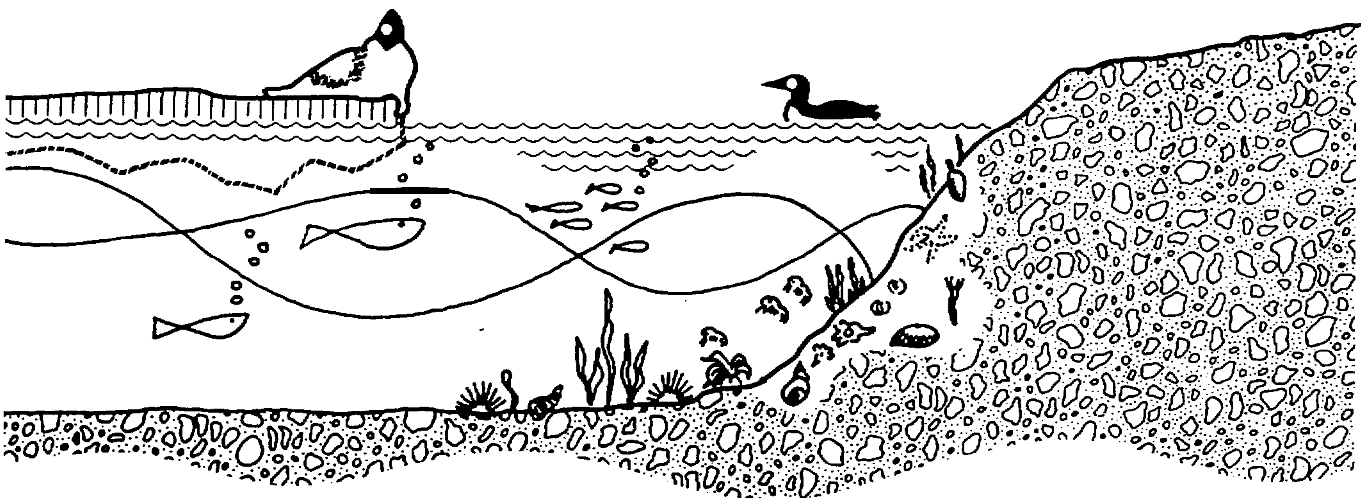
RU-606

DISCHARGE SYSTEMS



Baffin Island Oil Spill Project

WORKING REPORT SERIES

1981 STUDY RESULTS

The Baffin Island Oil Spill Project

OBJECTIVES

The Baffin Island Oil Spill (BIOS) Project is a program of research into arctic marine oil spill countermeasures." It consists of two main experiments or studies. The first of these, referred to as the Nearshore Study, was designed to determine if the use of dispersants in the nearshore environment would decrease or increase the impact of spilled oil. The second of the two experiments in the BIOS Project is referred to as the Shoreline Study. It was designed to determine the relative effectiveness of shoreline cleanup countermeasures on arctic beaches.

The project was designed to be four years in length and commenced in 1980.

FUNDING

The BIOS Project is funded and supported by the Canadian Government (Environment Canada: Canadian Coast Guard; Indian and Northern Affairs; Energy, Mines & Resources; and Fisheries & Oceans), by the U.S. Government (Outer Continental Shelf Environmental Assessment Program and U.S. Coast Guard), by the Norwegian Government and by the Petroleum Industry (Canadian Offshore Oil Spill Research Association; BP International [London] and Petro-Canada).

WORKING REPORT SERIES

This report is the result of work performed under the Baffin Island Oil Spill Project. It is undergoing a limited distribution prior to Project completion in order to transfer the information to people working in related research. The report has not undergone rigorous technical review by the BIOS management or technical committees and does not necessarily reflect the views or policies of these groups.

For further information on the BIOS Project contact:

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Correct citation for this publication:

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BAFFIN ISLAND OIL SPILL PROJECT
OIL DISCHARGE SYSTEMS

for
Environment Canada
Environmental Protection Service
Edmonton, Alberta

March 15, 1982

Prepared by: D F Dickins Associates Ltd.
3732 West Broadway
Vancouver, B.C. V6R 2C1

Under DSS Contract # 0SS80-00233

ABSTRACT

Two oil discharge systems were designed, constructed and operated as part of th'e 1981 Baffin Island Oil Spill Project. A dispersant / oil discharge system combined Lagomedio Crude and Corexit 9527 in a 10:1 mix with seawater at a 5:1 water to oil volume ratio, and discharged the resulting emulsion through 100 m of perforated pipe laid on the seabed perpendicular to shore in test Bay 9 of Ragged Channel, Cape Hatt, N.W. T. The mixture entered the water column through 39 orifices 6 mm in diameter and was allowed to sweep over the biological test area with natural currents. The report describes the design objectives, system components and field operation of both the diffuser (dispersed oil) system and the spill plate used for the surface oil spill in Bay 11.

Both oil discharge systems accomplished their design objectives resulting in two successful oil spills at Cape Hatt on August 19 and 27, 1981.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF PLATES

1.0 INTRODUCTION AND OBJECTIVES

In preparation for the 1981 oil discharges at Cape Hat t a design study was initiated in March of that year, to ensure an operational discharge system for testing in the south by June, and sub sequent deployment on Baffin Island in August/ September.

The principal design objective was to produce simple easil y transportable components that would distribute the oil in a controlled fashion in a uniform and correct concentration throughout the test areas. Prelimi- nary oil dispersant discharge concept development had been undertaken at the University of Toronto with laboratory measurements of realistic dispersed oil droplet size distributions (MacKay, 1981). In addition, a series of iterative calculations had been completed involving cliff erent flow rates, viscosity, discharge pipe submergence, pipe diameter and orifice size and spacing (Thornton, 1981). Starting with these theoreti- cal predictions a working dispersant discharge system was developed using light weight aluminum irrigation pipes in 6 m lengths joined by victaulic couplings. To provide for uniform exit flow along the entire pipe length (within 10%) it was decided at an early stage to mmbine the oil/ dis persant from the tank with seawater at about a 1:5 ratio. In this manner the viscosity of the resulting emulsion would be relatively insensitive to unpredictable changes in oil viscosity. With the larger total flow rate an almost uniform jet discharge could be guaranteed over the range of pipe slope and submergence expected in the field (1:5 to 1:10, 10 to 20 m).

The problems involved in obtaining a device to discharge the straight crude oil on the water surface were relatively minor. Modification of a commercially available foam filled car tire float to accept a hose con- nection at the bottom provided a low cost solution to this part of the project.

System design criteria were as follows:

Neat Oil Spill Device

Device to provide a smooth gentle flow of oil directly onto the water surface to minimize entrainment of oil droplets in the water column. This "spill plate" to float in a relatively stable upright position during discharge.

"Spill plate" position to be moved across the test area by small boat and tether line in order to coat beach uniformly according to prevailing winds at the time.

Oil/ Dispersant Discharge System

Required to evenly distribute oil and dispersant along 100 m of pipe in water depths to 20 m.

Pipe to be positioned on an anchor buoy tether about 1 m off the bottom (adjustable).

Number of orifices should number 50-70 and be spaced so as to compensate for changes in water depth, i.e., effectively an equal leakage rate per volume of water.

Sufficient pipe material, connectors, etc. to either change entry point from pipe end to centre (pipe orientation from perpendicular to parallel to the shoreline) or to construct a complete new system if first lost or deficient.

Desired pressure drop across each jet in the perforated pipe was in the range 9 to 15 kPa considered to produce a median drop size of about 5-10 μm (MacKay, 1981). Uniformity of jet flow along the pipe was to be within 10% of the mean design value. The concept depended on being able to create a cloud of dispersed oil particles whose size distribution would closely approximate that thought to result from the application of dispersant to oil on the sea surface.

Flow meters to be installed to allow continuous monitoring and adjustment of sea water and oil flow rates.

All equipment to be capable of air transport to the site in the event that the sealift was delayed or cancelled.

Oil/ Dispersant Storage and Supply

Two portable storage tanks capable of holding 15 m^3 of crude oil plus 1.5 m3 dispersant for at least one month without deterioration of the liner or release of plasticizers into the oil. Covered to prevent excessive weathering and keep out water.

Filter on suction line to prevent gross impurities from clogging discharge orifices.

Sufficient low temperature oil discharge hose to cover 200 m run (5 cm diameter). All joints pressure tested to 551 kPa.

Two outlet /flow control bypass /mixing return line packages to allow full recirculation of the tank contents.

Two seawater suction pumps capable of 220 ℓ /rein at up to 35 m of head (one spare).

Two oil pumps to provide up to 45 ℓ /rein flow for 6 hours with pressure release safety valve.

2.0 SYSTEM DESIGN

Swan Wooster Engineering of Vancouver was provided with all preliminary conceptual designs and calculations and asked to select actual components for purchase. They checked flow conditions and sized pumps to cope with predicted operating cumulative head losses through all joints, valves, flow meters and hoses. The Appendix shows their design checks together with predicted flow variation along the pipe under different conditions of oil viscosity and water depth. Maximum worst case deviation from average jet flow was 11. 6% in the deepest ten jets only. Flow along the rest of the pipe was constant within 5%.

Taking into account elevation, friction, orifice and seawater head losses the centrifugal seawater pump was selected to supply 220 Q /rein at a 55 psi, the positive displacement oil pump, 45 ℓ /rein at 36 psi (50 psi specified to allow for significant cliff erences in oil viscosity). Actual emulsion viscosities were derived from tests conducted at the University of Toronto in April 1981. Results showed a variation from 2.1 cP for salt water to 3.2 cP for a 1:10 emulsion at 5°C. Straight oil viscosity measured at 0° C in an Ostwald Viscometer was 440 to 460 cP with no noticeable wax deposition,

Figure 1 shows a flow diagram of the final oil/ dispersant system design. Plates 1 through 5 show components of the system, including swimming pool (tank), pumps and piping and the aluminum sparger prior to deployment off shore (see Section 3. O). Plate 6 shows the oil spill plate developed from a standard dock float.

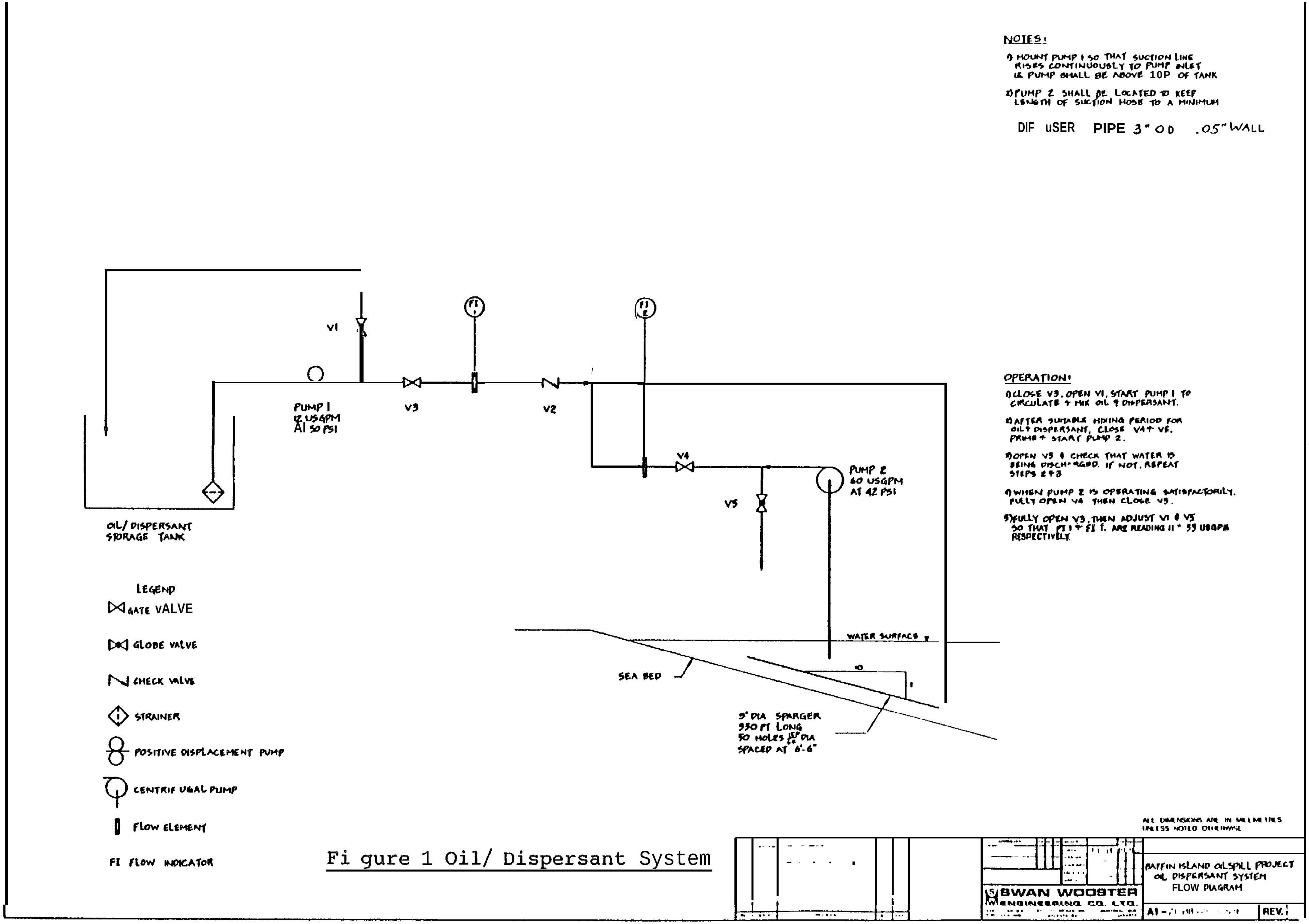
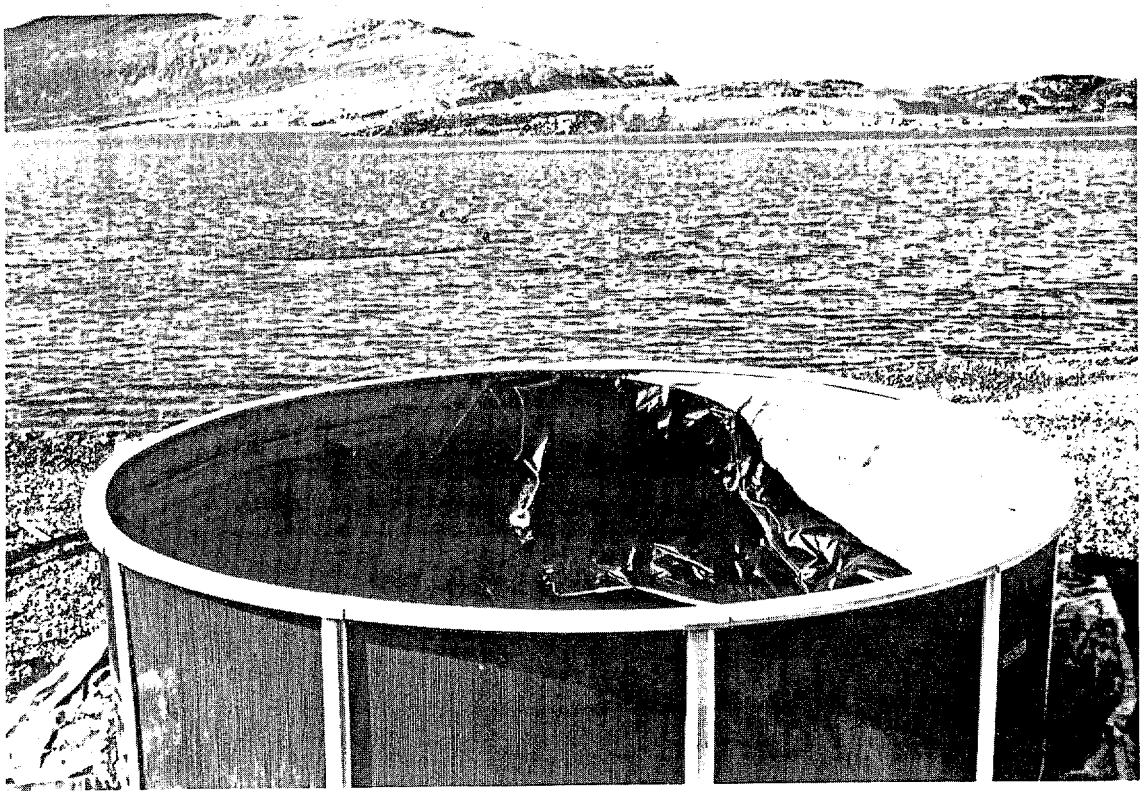
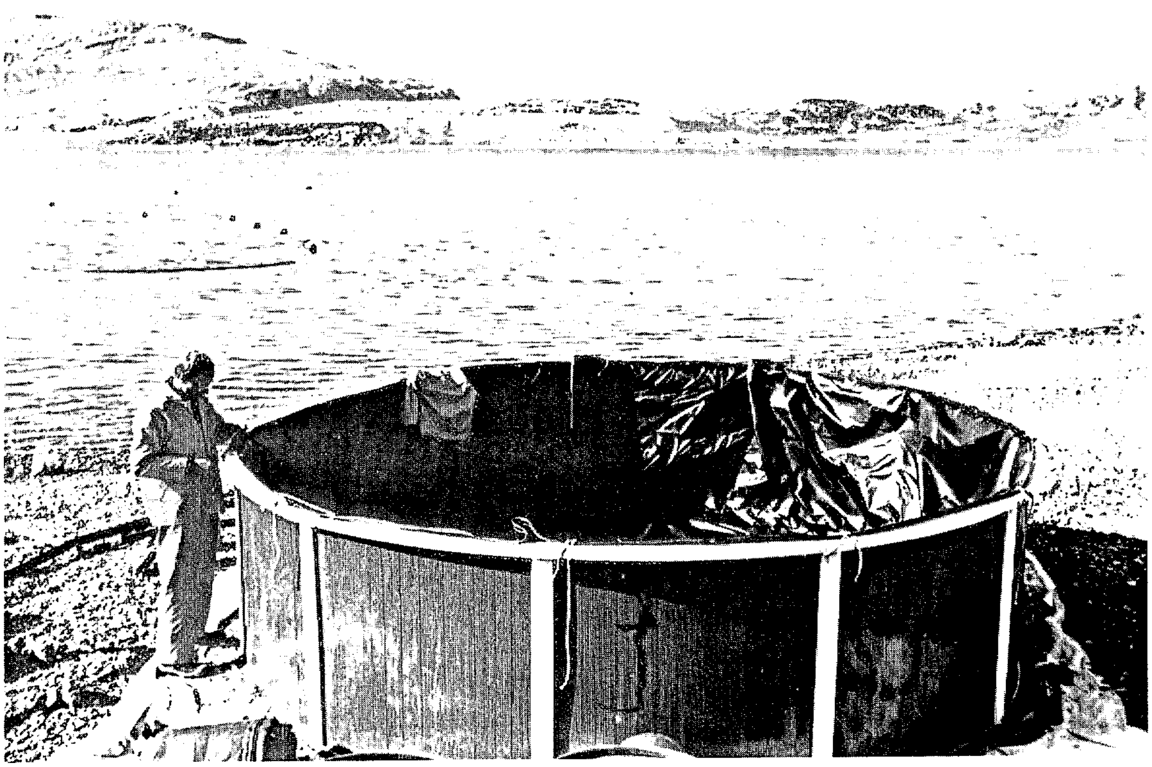


Figure 1 Oil/ Dispersant System



Plates 1 and 2

Final assembly of the 17 m^3 capacity swimming pool with special oil liner being installed inside standard vinyl liner (Shelter Rite XR-5 fabricated by Ancient Mariner, Vancouver).



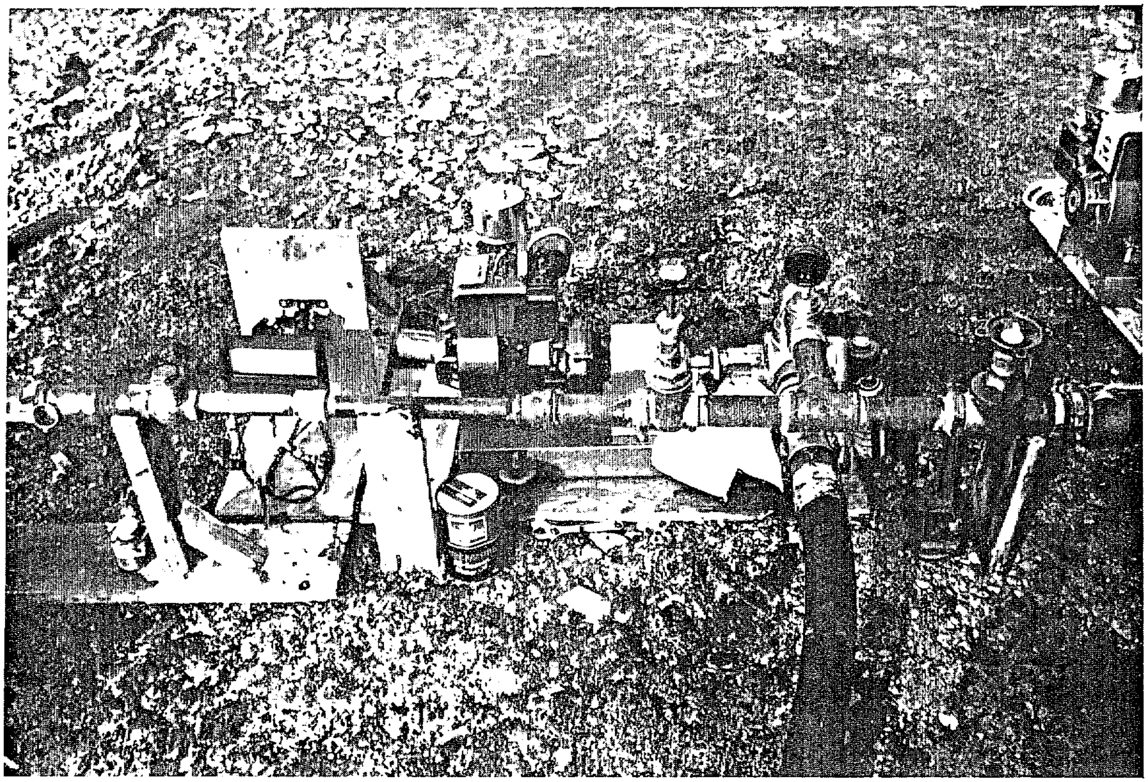


Plate 3 Oil Pump (Roto King) with inlet from tank (black hose) return circulation loop (to right - green valve) and main oil discharge through orifice flow meter (Annubar/Dover) to join seawater flow - below.

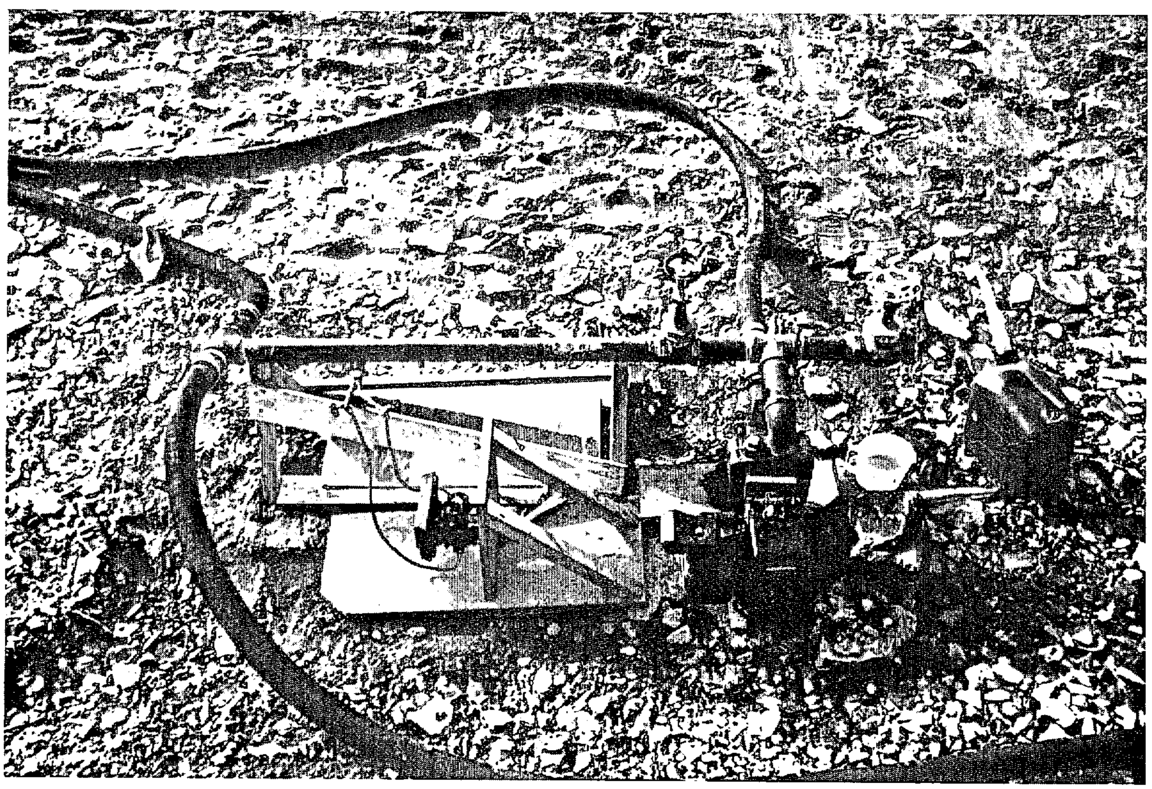


Plate 4 Water Pump (Jacuzzi) showing seawater intake line pumping from 5 m depth offshore, water flow meter (long pipe section) and T junction where oil mixed with the seawater (left end of pipe).

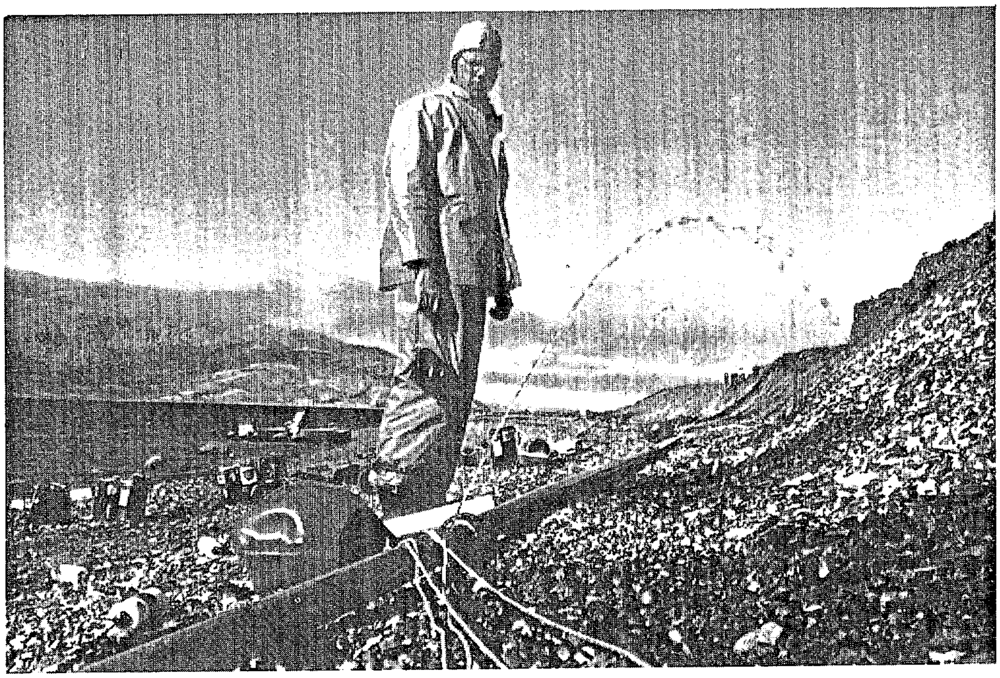


Plate 5 Dryland test of discharge system to demonstrate uniform jet flow and check connections.

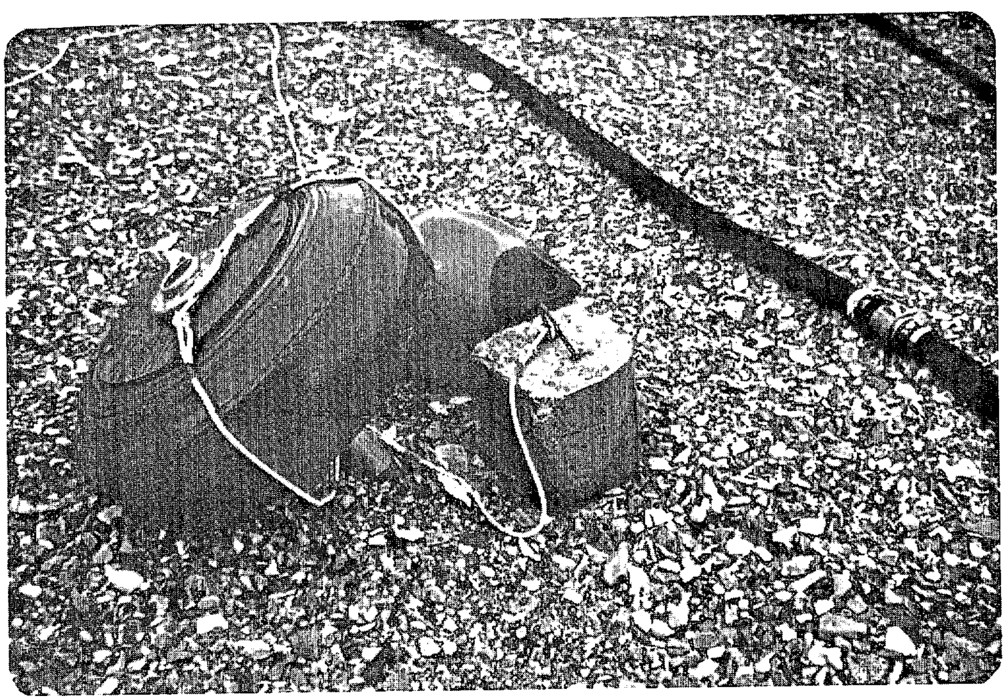
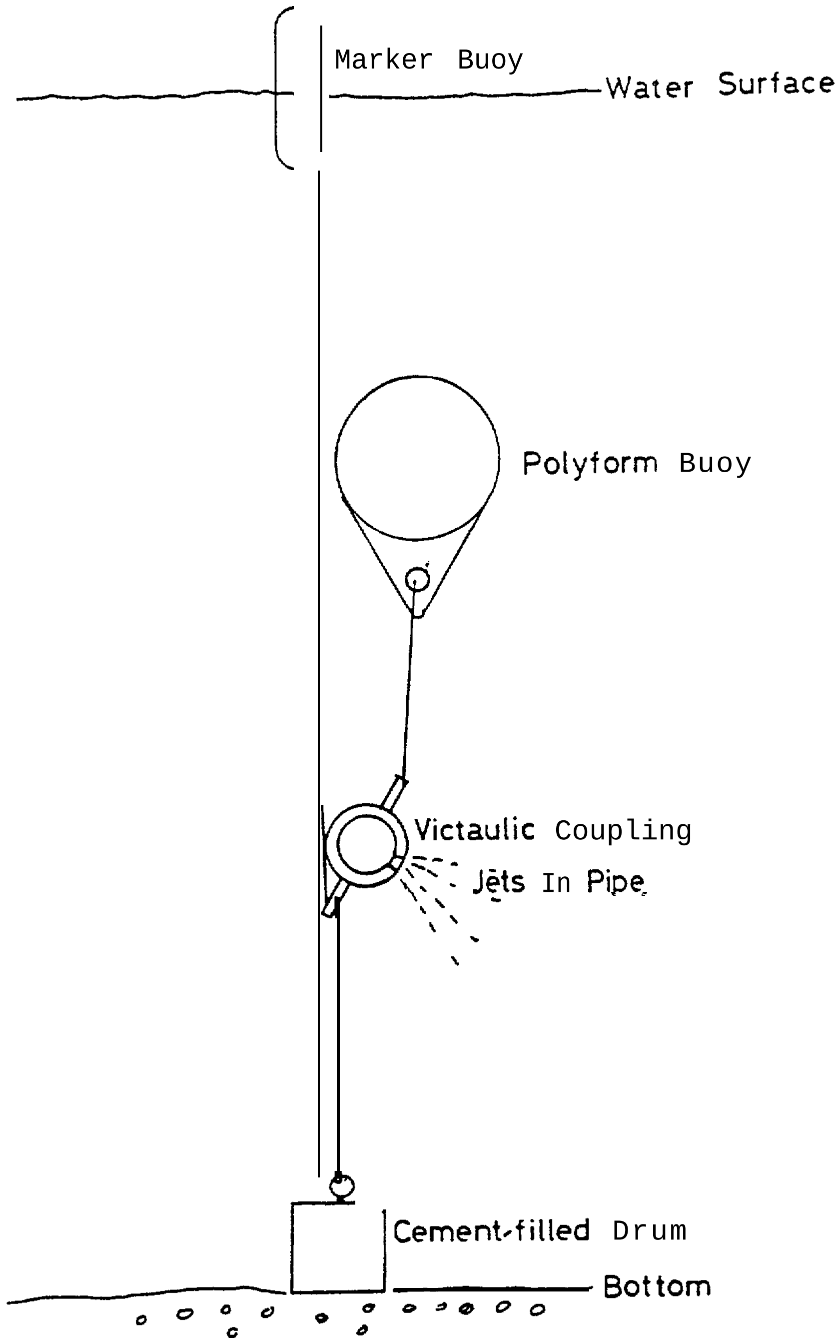


Plate 6 Oil Spill Plate showing anchor to damp out motions of the float in waves, pipe with screw connection for discharge hose leading from the tank.

3.0 DEPLOYMENT

The diffuser system was first deployed and operated in a dye test conducted on June 11, 1981 at Cordova Spit near Victoria, B.C. This site was chosen for its similar bottom slope (1: 5) and currents to those expected at Cape Hatt (6-8 cm/sec vs 5-10 cm/see). To more closely simulate the actual density of the oil/seawater mix to be pumped during the oil spill, the 15,200 ℓ tank at Cordova Spit was filled with fresh water. Four litres of Rhodamine B dye were added to this water prior to pumping out 12,700 ℓ over a 50 minute period. A full description of the results from the southern trial is contained within a report by Seakem Oceanography Ltd. (Green, July 16, 1981).

The diffuser pipe itself was suspended 1 m above the ocean bottom by standard 20 kg submerged buoys pulling against 50 kg steel anchors positioned every 6 m along the 100 m pipe. Figure 2 shows the mooring system used at Cordova Spit and the initial location tested at Cape Hatt. The final deployment of the diffuser in Bay 9 eliminated the mooring in order to place the pipe directly on the bottom. Plate 7 shows the anchors being deployed along the pipe from a sea truck in June 1981. At Cape Hatt a helicopter was successfully used to deploy the anchors with lines and marker floats attached. Final rigging of the system involved letting the pipe flood and sink to the bottom under its own weight with all lines slack, pulling the pipe in to a specified distance from the anchor using a line from the surface through a one way cleat adapted from a conventional sailboat fitting, and finally pulling the buoys beneath the water surface with a similar cleat arrangement. The end result was a pipe floating a set distance above the bottom. The system allowed any angle of jets by simply rotating the pipe relative to the victaulic couplings during assembly on the beach.



DIFFUSER PIPE ANCHORING SYSTEM

Figure 2

Plate 7 Anchor deployment along the floating diffuser pipe Cordova Spit, June 1981.

The mooring system was designed to operate without diver assistance if necessary. In practice the presence of divers was invaluable and made the entire operation much easier. Plate 8 shows divers at Cape Hatt making final adjustments to the pipe in shallow water.

Design changes resulting from the southern field trial were limited to small items such as clips and brackets. The major benefit of the Cordova Spit test was that it confirmed the basic soundness of the system and proved that the diffuser could be successfully deployed, even in a severe wind condition. An unintended result was the idea of directing the jets into the prevailing current to encourage mixing.

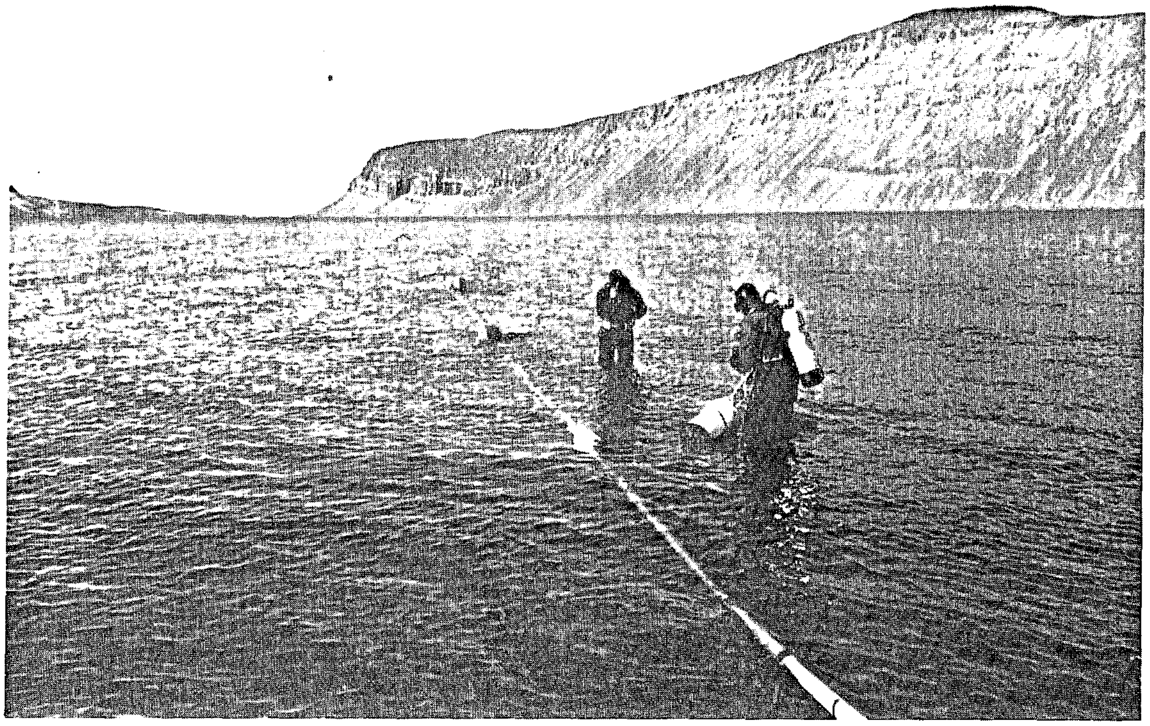
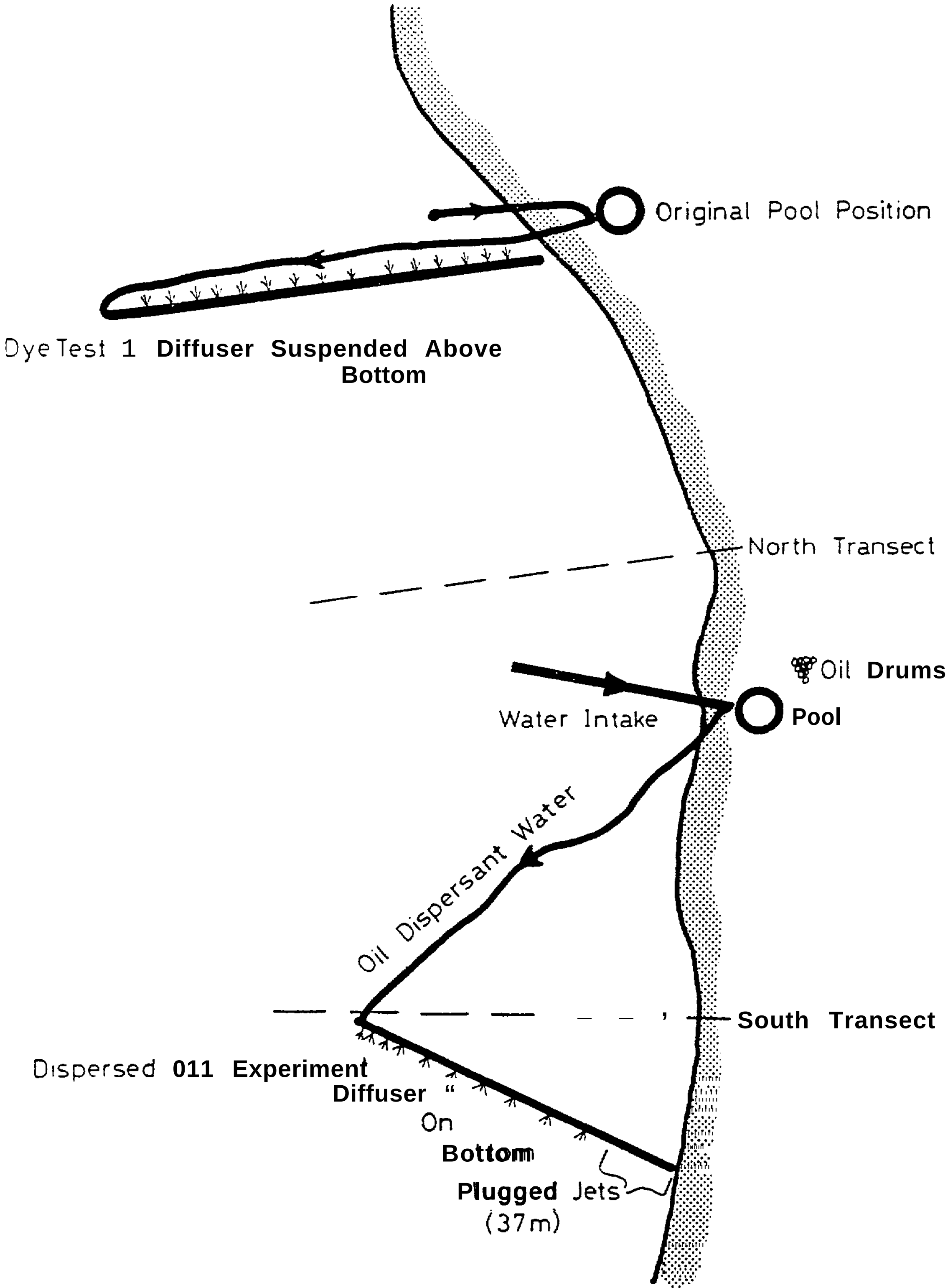


Plate 8 Divers at Bay 9, C. Hatt, making final adjustments to pipe in shallow water.

First deployment took place on August 13 at the north end of Bay 9 (Figure 3). Depth at the seaward end was 16 m. A seawater suction hose was installed in about 4 m of water (floated clear of the bottom to prevent sucking debris into the pump). The oil/dye hose entered the diffuser pipe from the seaward end. This feature was incorporated at an early stage in the design so that the cumulative internal fluid friction losses along the pipe would be effectively cancelled by the natural head gain between deep and shallow ends.

Fifty holes were drilled in the pipe (0.6 cm dia.) with spacings gradually increasing from 1.1 m in deep water to 6 m nearshore (see Appendix).



BAY 9 OIL DISCHARGE SYSTEMS

Figure 3

The first dye test using the diffuser in Bay 9, took place on August 16, with the jets pointed north and angled down at 45° to encourage contact with the sediments. Results from this test were disappointing in that there was a very slow uneven flow to the south and a rapid transfer of nearshore dye north into Bay 10. Ongoing work by the oceanographic group (Reimer, deLange Boom, Buckley) had by this date concluded that the probability of achieving sustained southerly flow through Bay 9 was extremely low (see Reimer, 1982). In spite of the difficulties with terrain for the pool site and longer hose lengths required, a decision was made to relocate the entire discharge system to the south end of Bay 9.

Plate 9 shows the pool at the final location prior to installing the oil liner. The diffuser is laid out along the beach with floats to assist moving the pipe into position. In order to save time and guarantee contact between the dispersed oil plumes and the sediments the pipe was laid directly on the bottom and snugged up to anchors by divers. Short lengths of rebar were attached to each joint to prevent the pipe from rolling with current or wave action nearshore. Plate 10 shows the diffuser pipe in final position just prior to being sunk.

The shore end was about 22 m south of the most southerly biological transect marker. The seaward end was in 16 m of water close to the transect line (Figure 3). Shoreline topography dictated the pool site and meant that some 150 m of discharge hose had to be used to reach the diffuser pipe end. A further 60 m of spare pipe sections (not drilled) were used to make up a water suction line with an intake at 5 m depth. This was done to ensure equality between the temperature of the discharge flow and water at the diffuser pipe level. Figure 3 shows the general arrangement of pipes and hoses. Plate 11 is an aerial view looking north in Bay 9 showing the pool, water suction line leading out to the "Baffin Queen" mooring, and diffuser pipe crossing the distinct coastal shelf before dropping out of sight into deeper water.

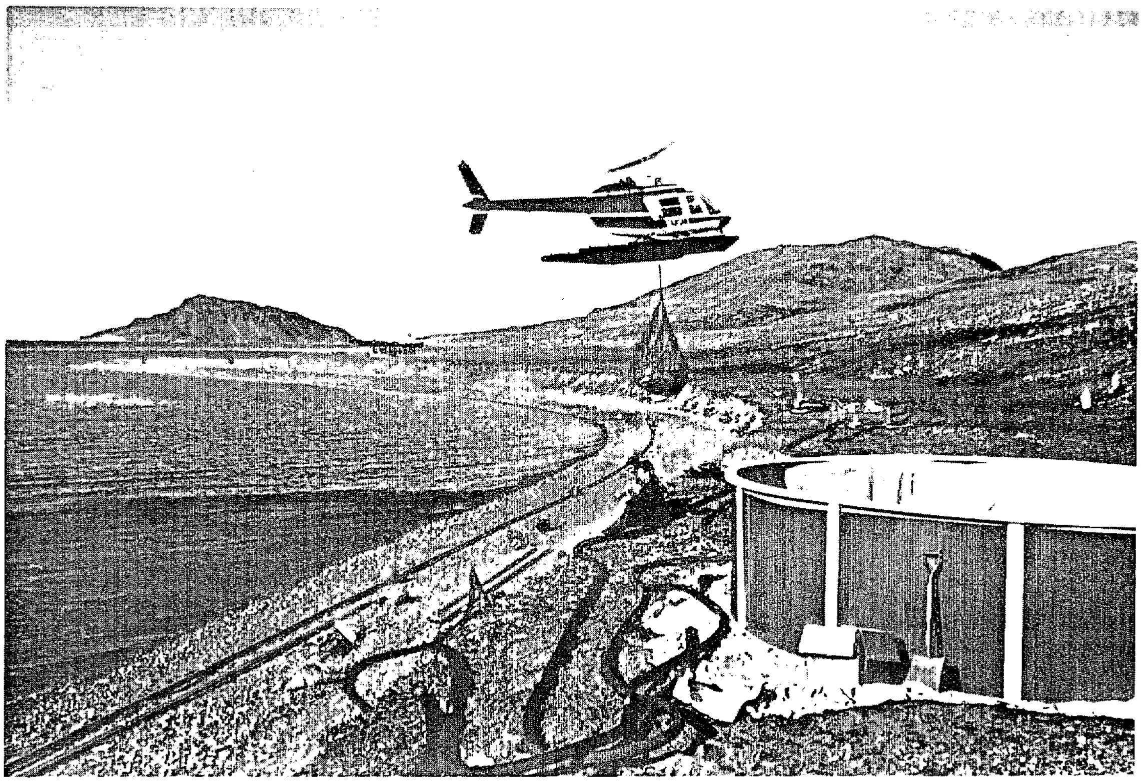


Plate 9 Pool in final location at south end of Bay 9. Diffuser pipe connected on beach ready for deployment.

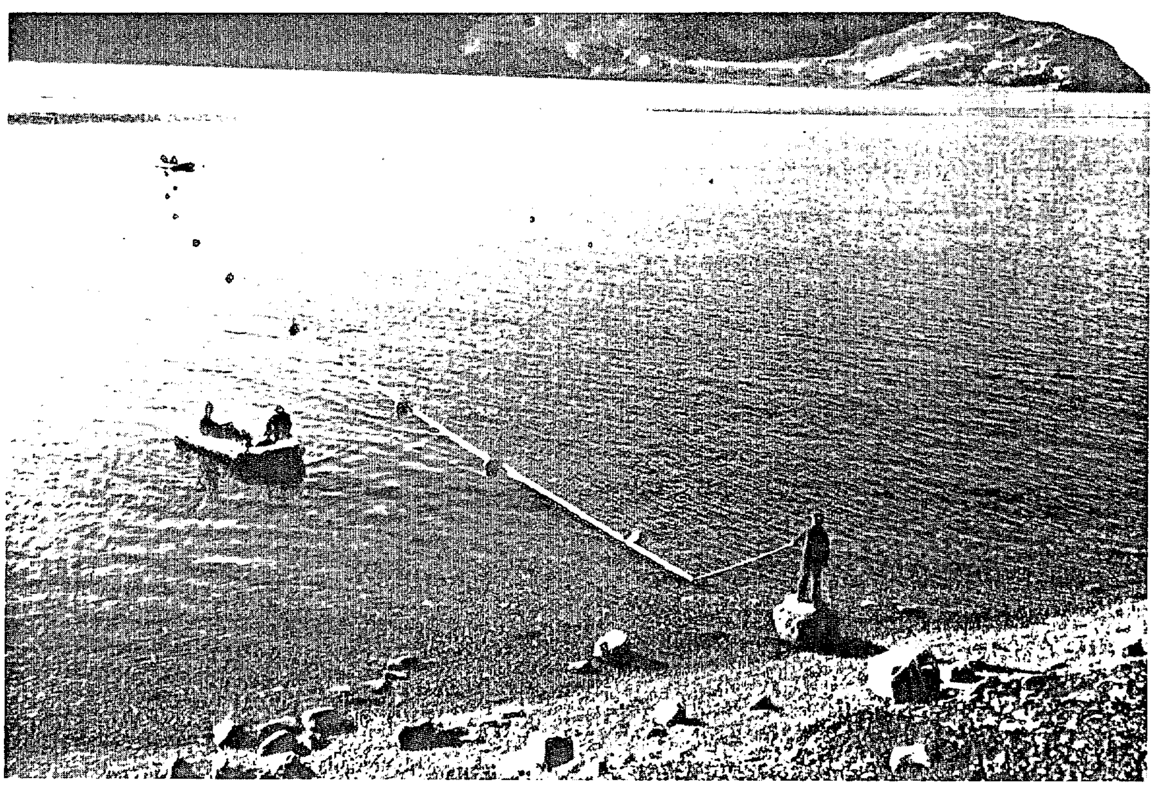


Plate 10 Diffuser pipe floating 100 m offshore during deployment.

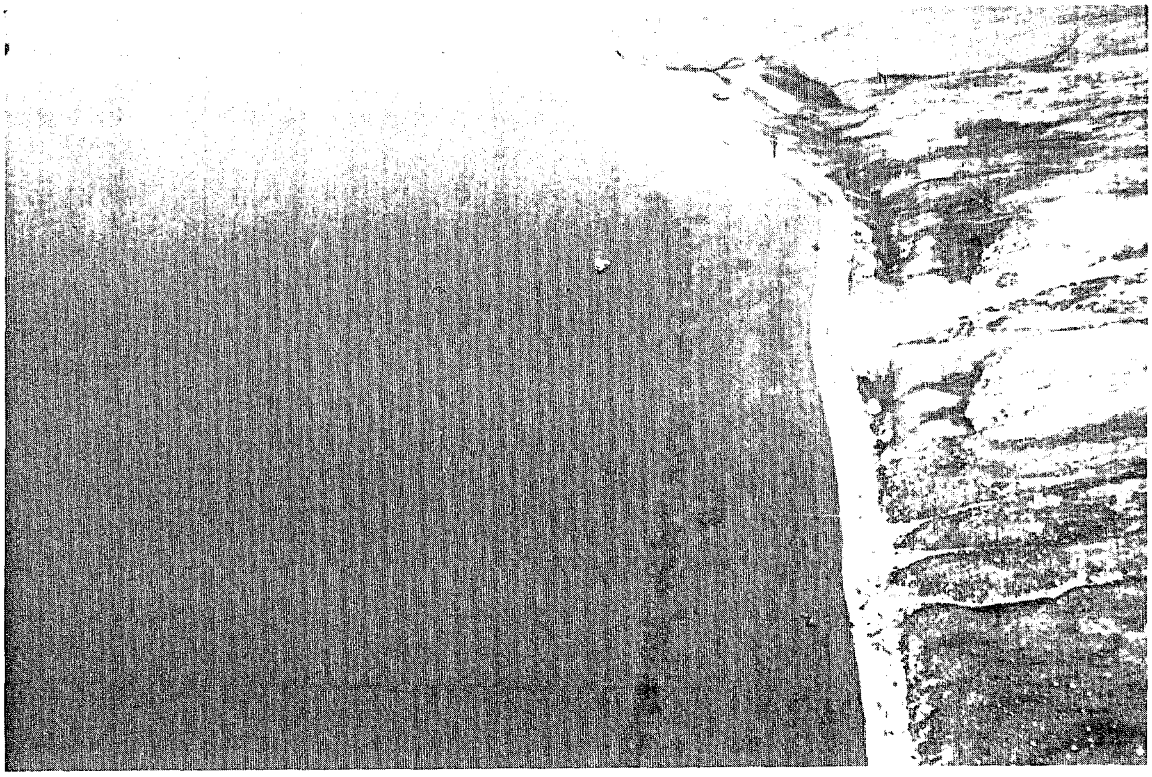


Plate 11 Aerial view looking north in Bay 9. Note the diffuser pipe and water suction line visible under water.

Two dye tests were conducted on August 22 and 25 with the diffuser in the new location. Results were satisfactory y, with the dye contacting the bottom sediments throughout the biolog ical test areas. Dye from the 11 jets in shallow water less than 2 m , moved once again in the opposite direction to deep water flow. As a result of these dye tests, it was decided to use the diffuser pipe without further adjustment to position, but with the nearshore jets plugged.

Plate 12 shows Bay 9 on the day of the dispersed oil experiment with the covered tank full of oil, and stockpiled empty drums off to one side e The pool was filled on August 26 (75 drums). Dispersant (7.5 drums) was added about 1/3 of the way through the loading. Oil and dispersant in the tank were passed through a recirculation loop for four hours on August 26 (2000-2400) and again for two hours on the morning of the test day (0830-1230). Circulation ceased forty minutes before discharge pumping started.

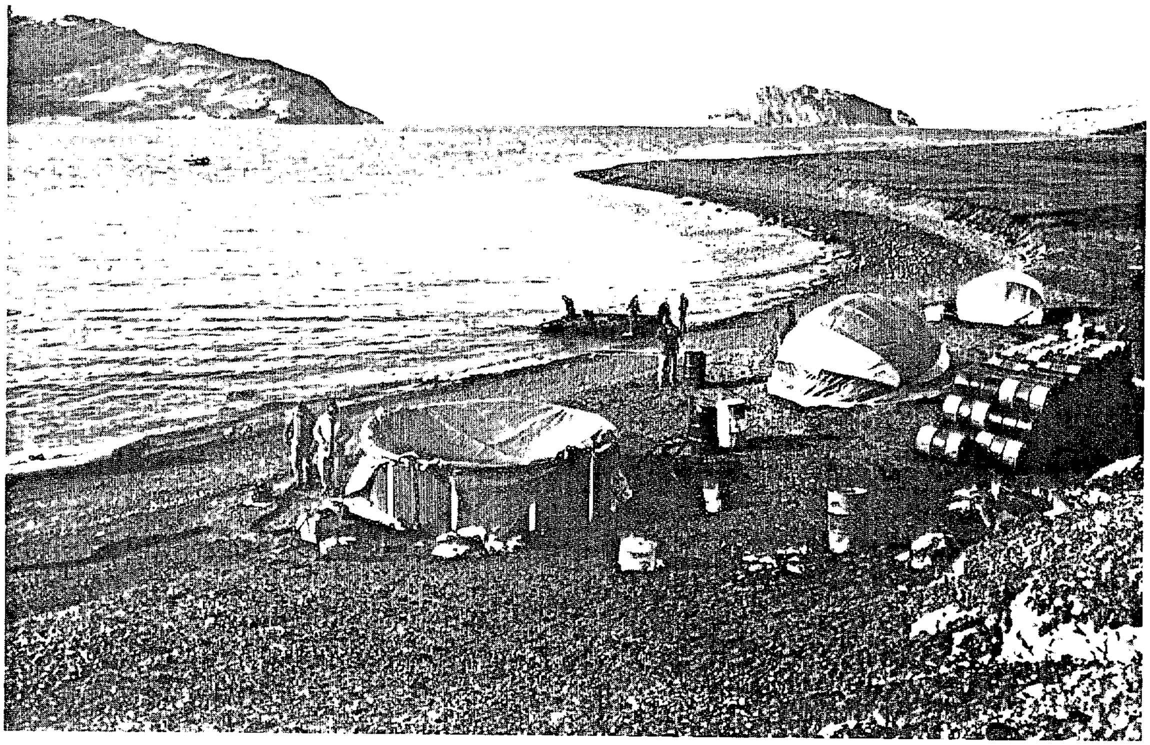


Plate 12 General view of Bay 9 showing oil filled pool and stockpiled drums.

Table 1 contains details of the dispersed oil spill.

Plate 13 shows the surface appearance of Bay 9 with the surface oil moving south before being swept back north through the test area (see Reimer, 1982 for an explanation of the oceanography governing final oil distribution) .

Plate 14 is an underwater photograph of the oil/dispersant plume (W. Cross). Plate 15 shows the tap at the onshore end of the pipe to allow regular sample collection. Plate 16 is a view inside the "command" tent showing a visual determination of oil/ water ratios.

Table 1 Dispersed Oil Discharge
August 27, 1981

Time	Flow Rates Oil (ℓ/min)	Flow Rates Water (ℓ/min)	Ratio Water/Oil	Comments
1310-1410	33.6	200	6	Start Pump 1335-1342 only oil flow at 15 ℓ/min
1410-1510	33.6	200	6	
1510-1610	43.8	200	4.6	
1610-1710	47.0	200	4.3	
1710-1830	40	200	5.0	
1830-1935	44	150	3*4	
1935-1943	44	210	4.8	Pump Stopped
Mean	41	194	4.9	

Volume Remaining in Tank: 2 drums (recovered)

Drained From Pipe: 1 drum (oil + dispersant + water)

Volume of Oil/Dispersant Discharged: 16 m^3

Total Time of Discharge: 6 hours, 23 minutes

Oil Temperature: +3.5°C

Water Temperature (Discharge): +2.7°C

Water Temperature (Ocean) 5 m: +2.54°C

12 m: 2.33°C

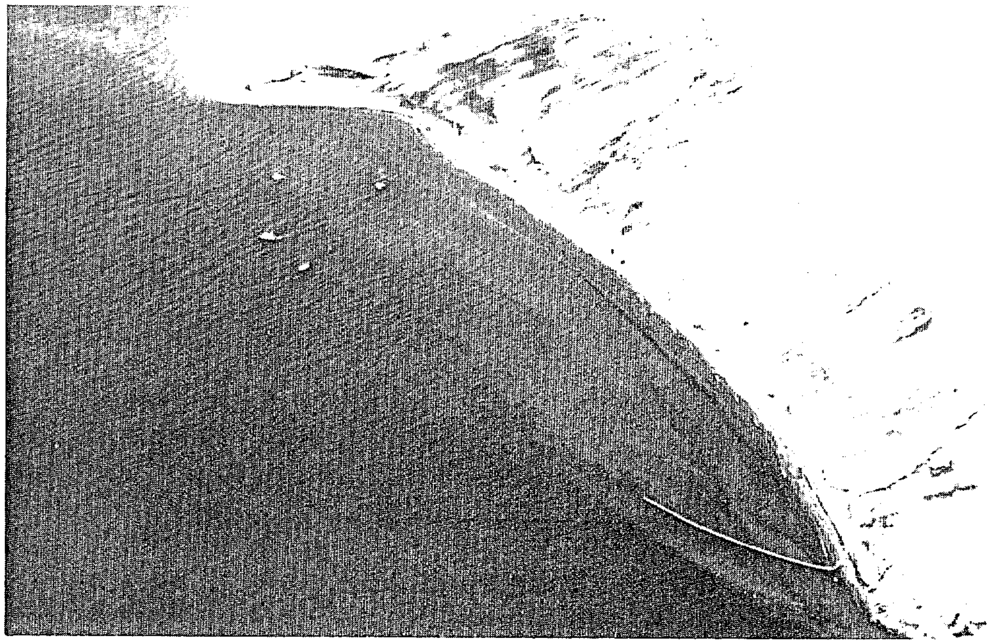


Plate 13 Aerial view of dispersed oil, Bay 9, August 27, 1981.

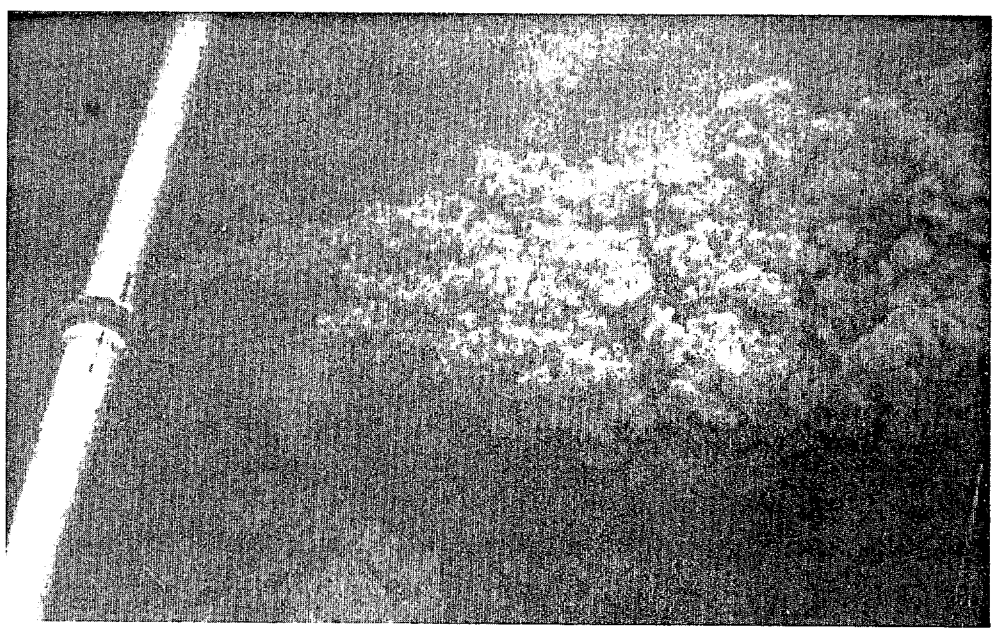
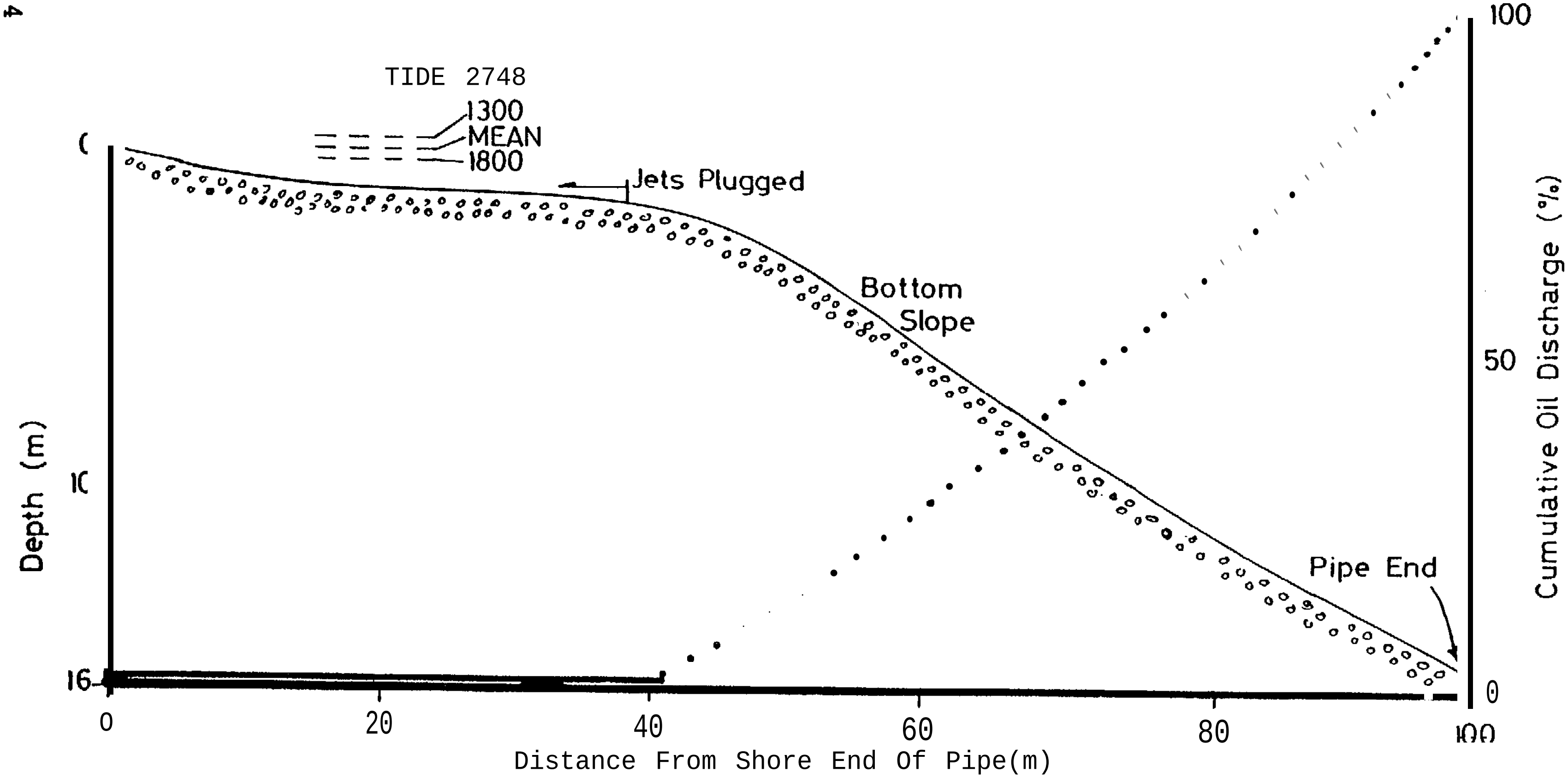


Plate 14 Underwater view of oil/dispersant emulsion jet plume (Cross).

Plate 15 Sampling emulsion during discharge.

Plate 16 Checking oil/ water ratio from pipe samples.

Figure 4



DIFFUSER PROFILE BAY 9

Figure 4 shows the bottom profile along the diffuser pipe with tide levels on August 27 and zone of plugged jets. The same figure also shows the cumulative percent volume of oil discharged with distance out from shore.

In summary, the diffuser system worked extremely well in spite of the complex nearshore oceanography in Bay 9.

Following the discharge the pipe was retrieved and the oil pool plus liner burned *in situ.*

The Bay 11 straight oil discharge system was comparatively easy in assembly and operation compared with the diffuser pipe. The same neoprene Arctic petroleum discharge hose and positive displacement 3 hp pump were used to transfer 15 m3 of oil from the swimming pool tank off shore to a moving spill plate. This device was tested while pumping water by moving through a wide arc reaching from the south to north transect lines. However, winds on August 19, the day of the surface spill, remained fairly constant from the west, allowing an almost fixed position for the spill plate throughout much of the discharge. Figure 5 shows the general layout of the Bay 11 oil discharge system. Plate 17 shows the oil gushing out of the converted tire float and spilling over the sides onto the water. Plate 18 shows an aerial view of the oil streaming east onto the beach at an early stage in the test. Note the tide is near its high point. Plate 19 is a view near the end of the discharge at low tide showing the uniform coating of oil over the entire beach (Plate 20).

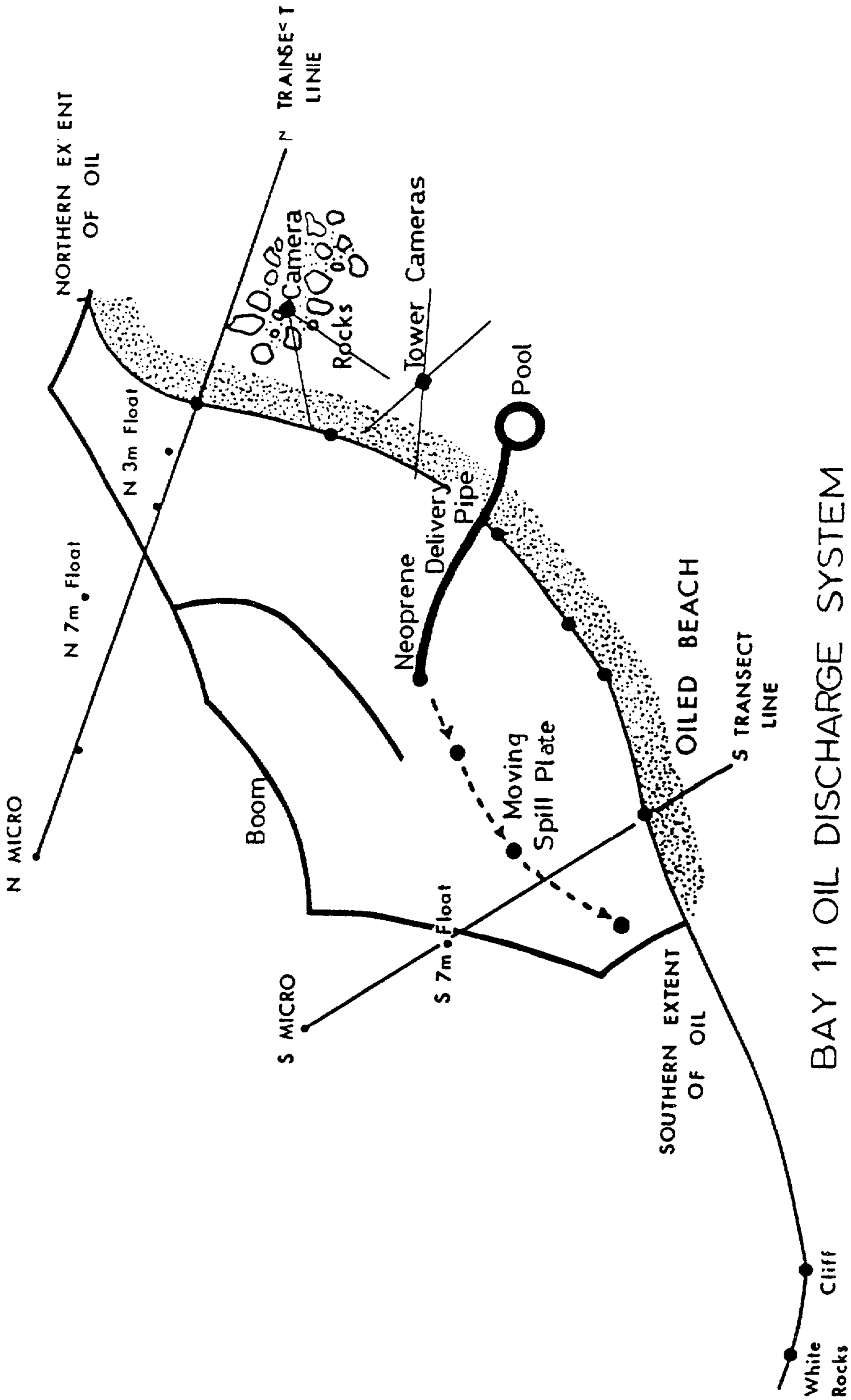

BAY 11 OIL DISCHARGE SYSTEM
NORTHERN EXTENT OF OIL
N MICRO
N 7m Float
N 3m Float
Camera
Rocks
Tower Cameras
Pool
Neoprene Delivery Pipe
Boom
Moving Spill Plate
OILED BEACH
S TRANSECT LINE
S MICRO
S 7m Float
SOUTHERN EXTENT OF OIL
Cliff
White Rocks

Figure 5

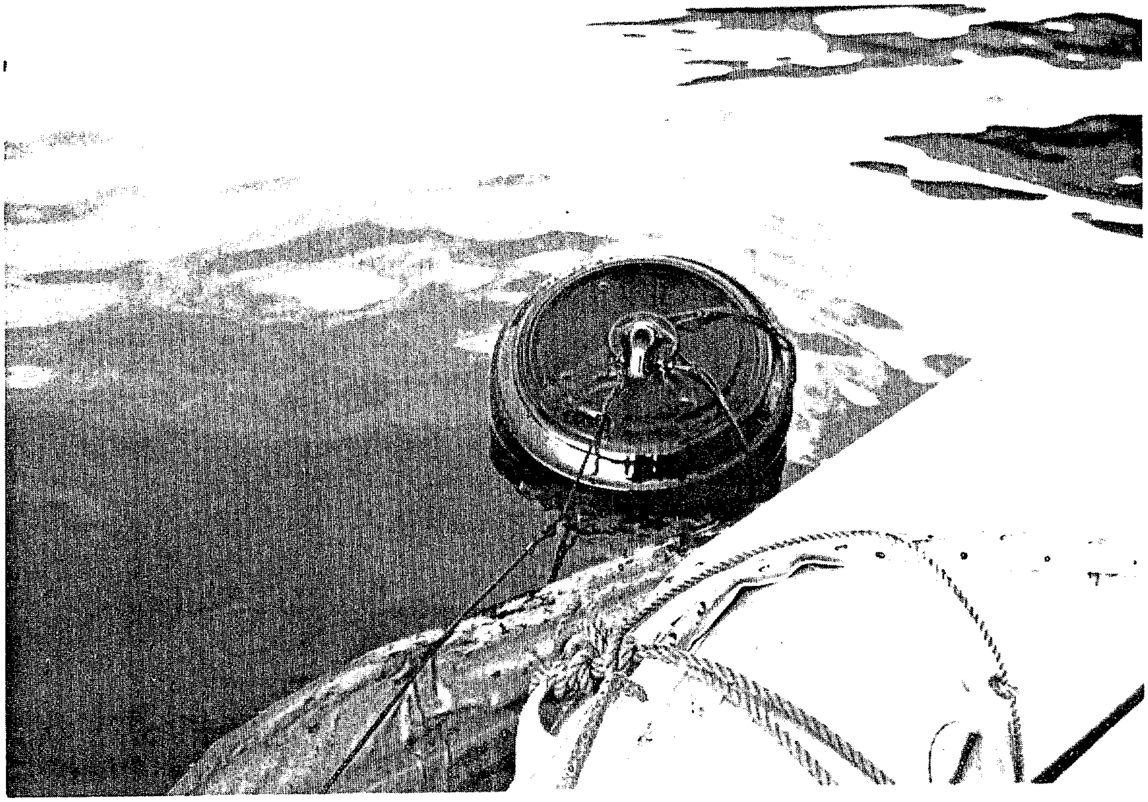


Plate 17 Oil spill plate in operation.

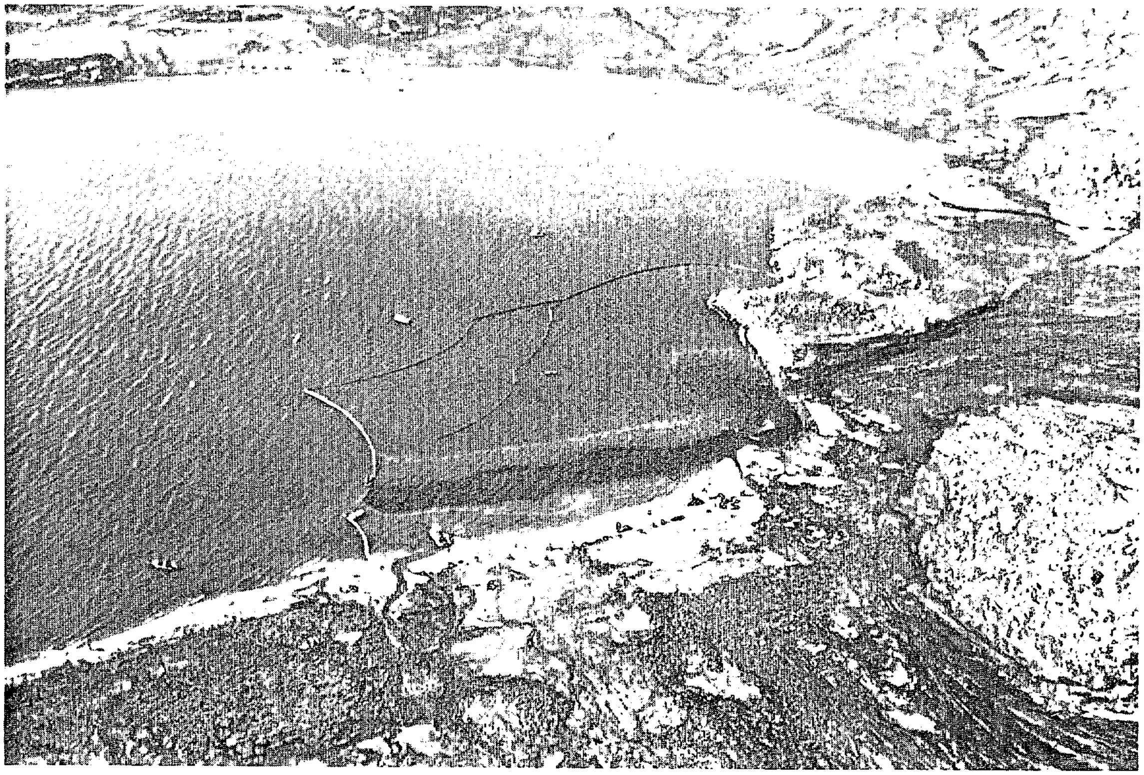


Plate 18 Aerial view of Bay 11, August 19, ≈ 1630 - 45 min. after start of pumping.

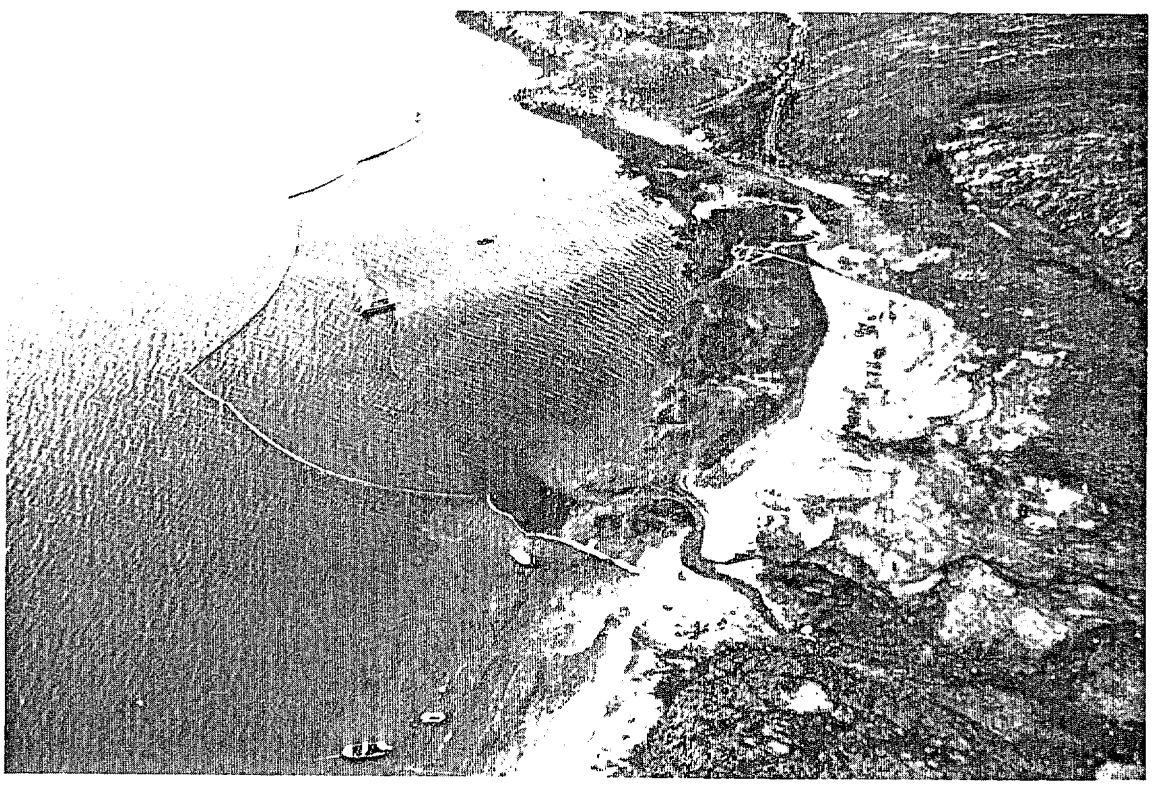


Plate 19 Aerial view about 2000, 4 hours after pumping began.

Table 2 Flow Rates Bay 11 Surface Spill
August 19, 1981

Time	Flow Rate	
1522-1631	25 l/rein	- First Oil Offshore at 1550
1631-1732	44	
1732-1825	39	
1825-1925	42	
1925-2037	38	
2140		Ended Pumping

Total Volume Pumped: 15 m^3 (75 drums)

Total Pumping Time: 6 hours

Note: Discharge continued until water was seen coming out of spill plate.

Plate 20 Beach appearance following oil discharge in Bay 11.

4.0 CONCLUSIONS

Both oil discharge systems were an unqualified success. The choice of light weight aluminum irrigation pipe proved to be both strong and readily transported, without the problems previously associated with achieving uniform orifices in plastic tubing (Topham, personal communication).

'I'he spill plate although very simple in design accomplished the objective of uniformly coating the beach.

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THORNTON, D.E. Calculations re BIOS Oil Discharge. Correspondence of March 20, 1981.

ACKNOWLEDGMENTS

Many people contributed to the success of the oil discharge systems, in particular:

- Blair Humphrey in the mooring system design and execution.

- Howard Smith of Swan Wooster Engineering, Vancouver, in hydraulics evaluation and component selection.

- Institute of Ocean Sciences in the loan of boats and operators.

- Seakem Oceanography, Peter Blackall, Gary S ergy, Ernie Reimer, Bodo deLange Boom, Joe Buckley and Don MacKay in assisting with assembly and deployment of pools and pipes.

- Doug Kittle, Norm Snow, Claude Rivet and W. Cross in diving operations.

Field work on the discharge systems was undertaken jointly by David Dickins and Dr. Dave Thornton.

APPENDICES

DESIGN CALCULATIONS - Thornton
- smith

VARIABLE HOLE SPACING

PUMP SPECIFICATIONS

FLOW METER GENERAL ARRANGEMENT

UNIVERSITY OF TORONTO
TORONTO, CANADA M5S 1A4

DEPARTMENT OF CHEMICAL ENGINEERING
AND APPLIED CHEMISTRY

April 6, 1981

Dr. D.E. Thornton
Environmental Emergencies Branch
Environmental Protection Service
15th Floor
Place Vincent Massey
Ottawa, Ontario
K1A 1C8

Dear Dave:

Re: BIOS

The emulsion viscosities at 5°C were:

Salt water	2.1 centipoise
1:5 emulsion	3.5 "
1:10 emulsion	3.2 "

We ran the Lago Medio oil through an Ostwald (capillary U tube) viscometer at 0°C. The oil had a consistent viscosity of 440 to 460 cP when run 12 times over 75 hours. There was no wax deposition.

Hope this is O.K.

Sincerely yours,

D. Mackay
Professor

cc. D.F. Dickins

Environment Canada / Environnement Canada
Environmental Protection / Protection de l'environnement

Ottawa, Ontario
K1A 1C8

March 20, 1981

Your file Votre référence

Our file Notre référence 4482-11

Mr. Dave Dickens
D.F. Dickens Limited
3732 W. Broadway
Vancouver, B.C.
V6R 2C1

Dear Dave,

RE: BIOS Project Oil Discharge

Please find attached some notes and calculations regarding the oil/dispersant discharge for the BIOS project.

The first set of notes include:

1. An equation for the leakage rate per unit length which is proportional to the water depth (PI)

2. An equation for the hole positions which will give a leakage rate proportional to the water depth (P2)

3. A sequential solution to the pipe flow problem (P3-4)

   The solution assumes the initial pressure and inflow rate is set and that the resultant leakage balances the inflow rate. If it does not, the input pressure (or number of holes, or size of holes) must be changed and the calculation rerun (and rerun!...). In the field, we will fix the number, size, and spacing of the holes and adjust the input pressure to ensure the flowrate is correct.

4. A BASIC computer program for the numerical calculation (P6-9).

   The program runs on the (~$350) Radio Shack TRS-80 pocket computer. You may wish to purchase one for the extra runs, or I will run mine using new input parameters if you want.

The second set of notes include a series of (rather rough) calculations, mostly using the program, regarding the pipe flow problem.

The main points are as follows:

1. It is possible, but not desirable, to discharge the crude oil/dispersant mixture through 100m, 2" ID, pipe with a slope of 10m in 100m. (P6). The frictional losses (essentially) balance the hydrostatic head gain (due to the density difference between the oil/dispersant and the water). The balance is not perfect all along the pipe and the flow out of

../2

different jets will vary by about 30%. The balance, however, is very delicate and slight changes in oil viscosity, pipe slope, or water **depth could** cause severe problems. For example, changing the oil viscosity by about 50% (from 0.094 to 0.150 PaS) causes such significant head losses that oil stops flowing out of the holes at about only ¼ way along the pipe (P8). The only way to accommodate this is to carefully select a larger pipe size. (Too large a pipe size causes as much mismatch in frictional loss and hydrostatic head gain as does too small a pipe). We do not have the luxury of changing pipe sizes in the field.

2. A 2" ID horizontal pipe with a centre connection would have about a 30% flow drop off out of the jets, meaning the pressure across the jets would fall off by about 60%.

   This means the flow rate from the lower-flowing jets would be very susceptible to variations in pipe height or tidal fluctuations. In this application, this pipe size is just too risky. (P7)

3. A 100m, 3" ID, horizontal pipe with centre connection could accommodate the oil/dispersant flow rate without too much frictional loss (and therefore pressure drop). (P7)

4. A mixture of oil/dispersant and water in a ratio of 1 to 10 would create too high a flowrate in, and therefore pressure drop along, a 2" pipe. (P4). Also the pressure drop of 225,000 **Pa** (about 2¼ atmos.) along the 200m x 2" discharge hose would necessitate a fairly powerful pump (P1)

5. A mixture of oil/dispersant and water in a ratio of 1 to 5 would be acceptable in either a sloping (P9-11) or horizontal (centre connection) 3" ID pipe. In either case the flow drop off is less than about 10% and the hydrostatic head variation with water depth is only about 300 Pa/m, so a 2m tidal variation of about 600 Pa is also less than 10% of the 10,000 - 13,000 Pa pressure difference in the pipe. For the 200m of 2" discharge hose, the pressure drop will be only about 3/4 atmosphere.

Conclusions:

1. I recommend a 200m x 2" diameter discharge hose leading into the deepwater end of a sloping 100m x 3" ID discharge pipe or into the centre of a similar horizontal pipe.

2. If the pipe is sloping, I suggest we discharge an oil/dispersant: sea-water 1:5 mixture. About 50 holes 6mm in **diameter at a pressure difference of about 13,000 Pa (0.13 atmos.) should create the correct flowrate.** The hole spacing will be variable and depend on the pipe slope and water depth. (See my calcul at ions for reasonable values).

. ../3

3. If the pipe is horizontal, either a similar mixture (flowrate), hole number and size (with even spacing) would be acceptable, or a discharge of oil alone may be OK (with ∿40 evenly spaced 3mm holes).

Don Mackay is currently making some measurements of oil droplet size distributions for oil/dispersant:water mixtures of 1:5 to 1:10 at a couple of turbulence levels bracketing the values expected in the pipe. He will also attempt to check the viscosity of the mixtures (I used 0.002-0.004 PaS in comparison with 0.0017 for cold seawater).

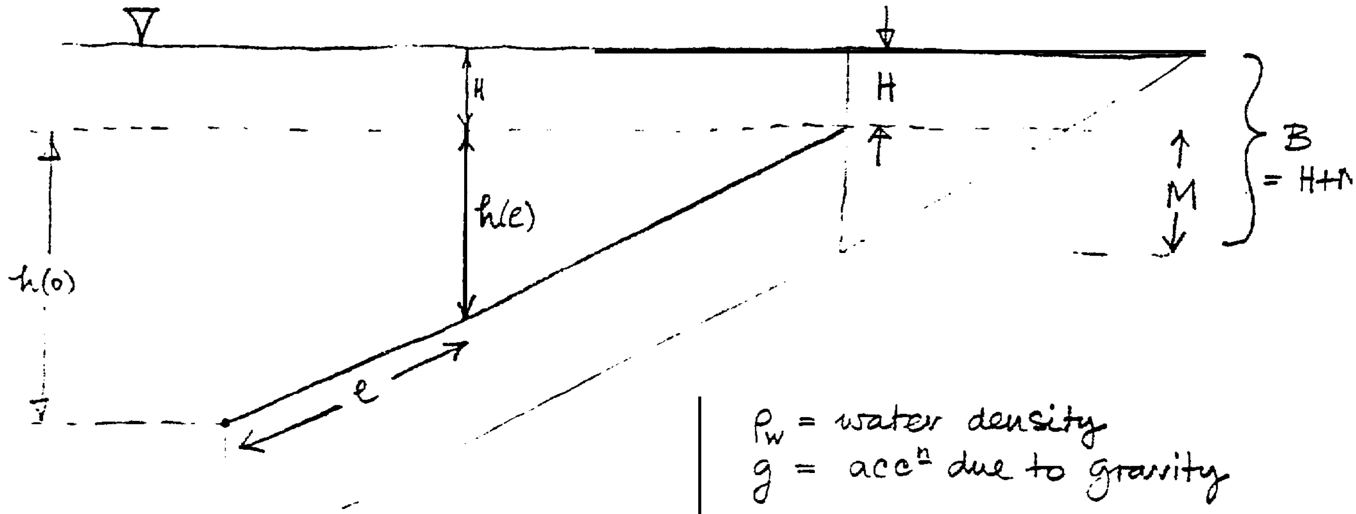
I look forward to hearing from you.

Yours truly,

D.E. Thornton, Ph.D.
Chief
Research and Development Division
Environmental Emergency Branch

Attach.
Ccc. : P.J. Blackall
Don Mackay
S.L. Ross

B:OE PROJECT : Sloping pipe discharge/variable hole spacing



/ ' "

...ulation of hole spacing

...ume $q(e) \propto B + h(e)$
the flowrate is proportional
the water depth.

$$q(e) = K\left[B + h(e)\right]$$

$$\int_0^L q(e)\,de = Q(0)$$

$$h(e) = h(0)\frac{(L-e)}{L}$$

$$Q(0) = K\int_0^L \left\{B + \frac{h(0)}{L}\left[L-e\right]\right\} de$$

$$= K\left[Be + \frac{h(0)}{L}\left(eL - \frac{e^2}{2}\right)\right]_0^L$$

$$= K\left[BL + \frac{h(0)}{L}\,\frac{L^2}{2}\right]$$

$$= KL\left[B + \frac{h(0)}{2}\right]$$

$$K = \frac{2Q(0)}{L\left[2B + h(0)\right]}$$

$$\boxed{q(e) = \frac{2Q(0)}{L}\left[\frac{B + h(e)}{2B + h(0)}\right]}$$

ρ_w = water density
g = accn due to gravity

ρ_o = oil density (or oil/water mix)
μ = oil viscosity (—— ——)
V = oil volume
T = discharge period
d = pipe diameter
L = pipe length
n = no. of pipe holes
H = pipe submergence
M = pipe height (above bottom)
$h(0)$ = max. pipe slope height
$Q(0)$ = input flow rate
$P(0)$ = input pressure

e = length along the pipe
$h(e)$ = pipe slope depth at e
$P(e)$ = internal pressure at e (relative to water outside)
$q(e)$ = leakage rate/m at e
$v(e)$ = oil velocity at e

a = hole diameter
w_j = jet velocity for j th jet
q_j = leakage rate from jet j

ume there are n holes at $\ell_1, \ell_2, \ldots, \ell_j, \ldots, \ell_n$ each

scharging at a rate of $Q(0)/n$

Then $\int_0^{\ell_j} q(\ell)\,d\ell = j \cdot \frac{Q(0)}{n}$

$$j\,\frac{Q(0)}{n} = \frac{2Q(0)}{L}\,\frac{1}{[2B+h(0)]}\left[B\ell + h(0)\left(\ell L - \frac{\ell^2}{2}\right)\right]_0^{\ell_j}$$

$$\frac{jL}{2n}\,[2B+h(0)] = B\ell_j + h(0)\,\ell_j - \frac{h(0)}{2L}\,\ell_j^2$$

$$\ell_j^2 - \frac{2L}{h(0)}\,[B+h(0)]\,\ell_j + \frac{j}{n}\,\frac{L^2}{h(0)}\,[2B+h(0)] = 0$$

$$\ell_j = \frac{\frac{2L}{h(0)}[B+h(0)] \pm \sqrt{\frac{4L^2}{h(0)^2}[B+h(0)]^2 - j\,\frac{4L^2}{n\,h(0)}[2B+h(0)]}}{2}$$

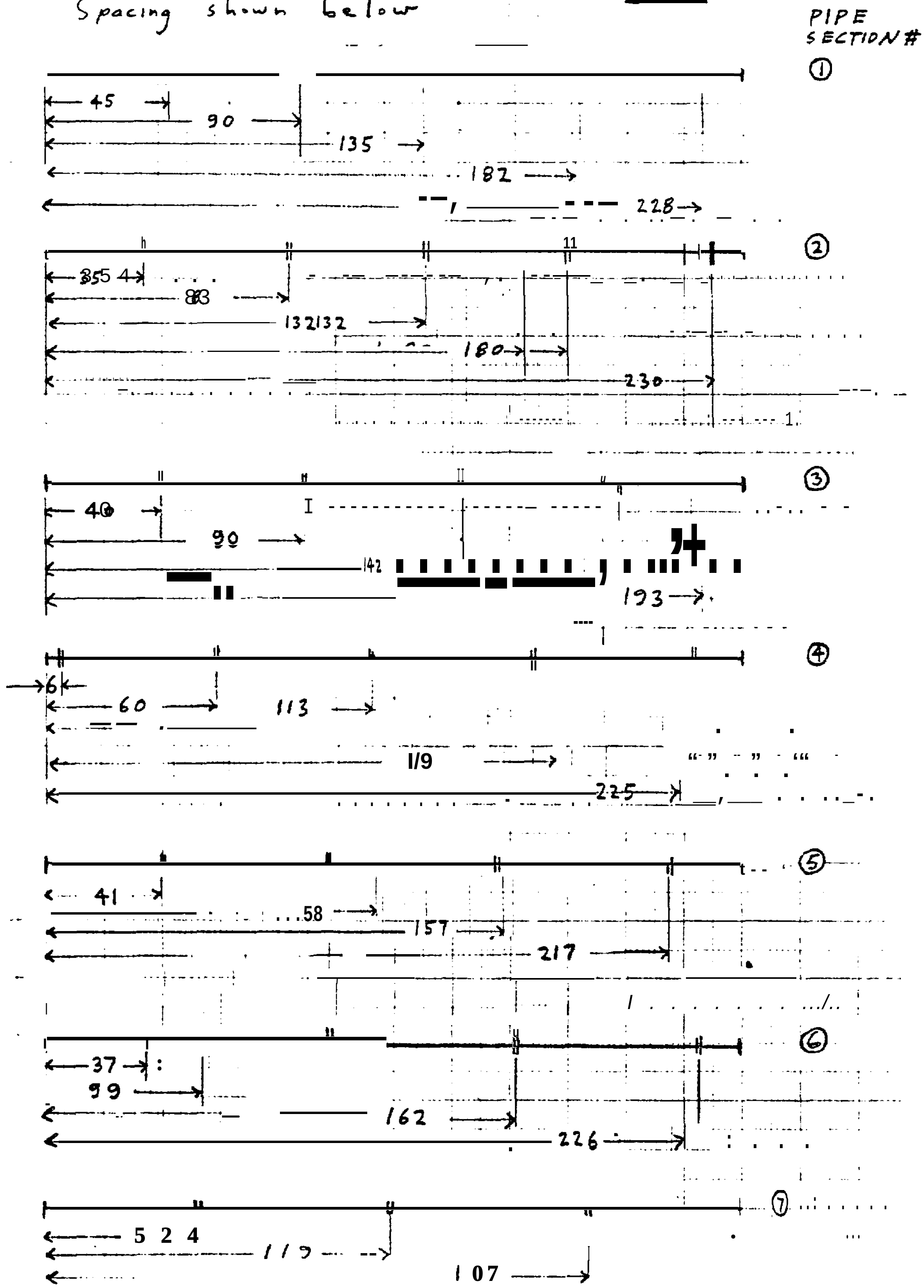
$$\boxed{\ell_j = L\left[\frac{B+h(0)}{h(0)}\right]\left\{1 - \sqrt{1 - \frac{j}{n}\cdot\frac{h(0)[2B+h(0)]}{[B+h(0)]^2}}\right\}}$$

∴ $\ell_n = L$, as it should.

PACIFIC IRRIGATION

OIL DISCHARGE PIPE 3 inch Al.

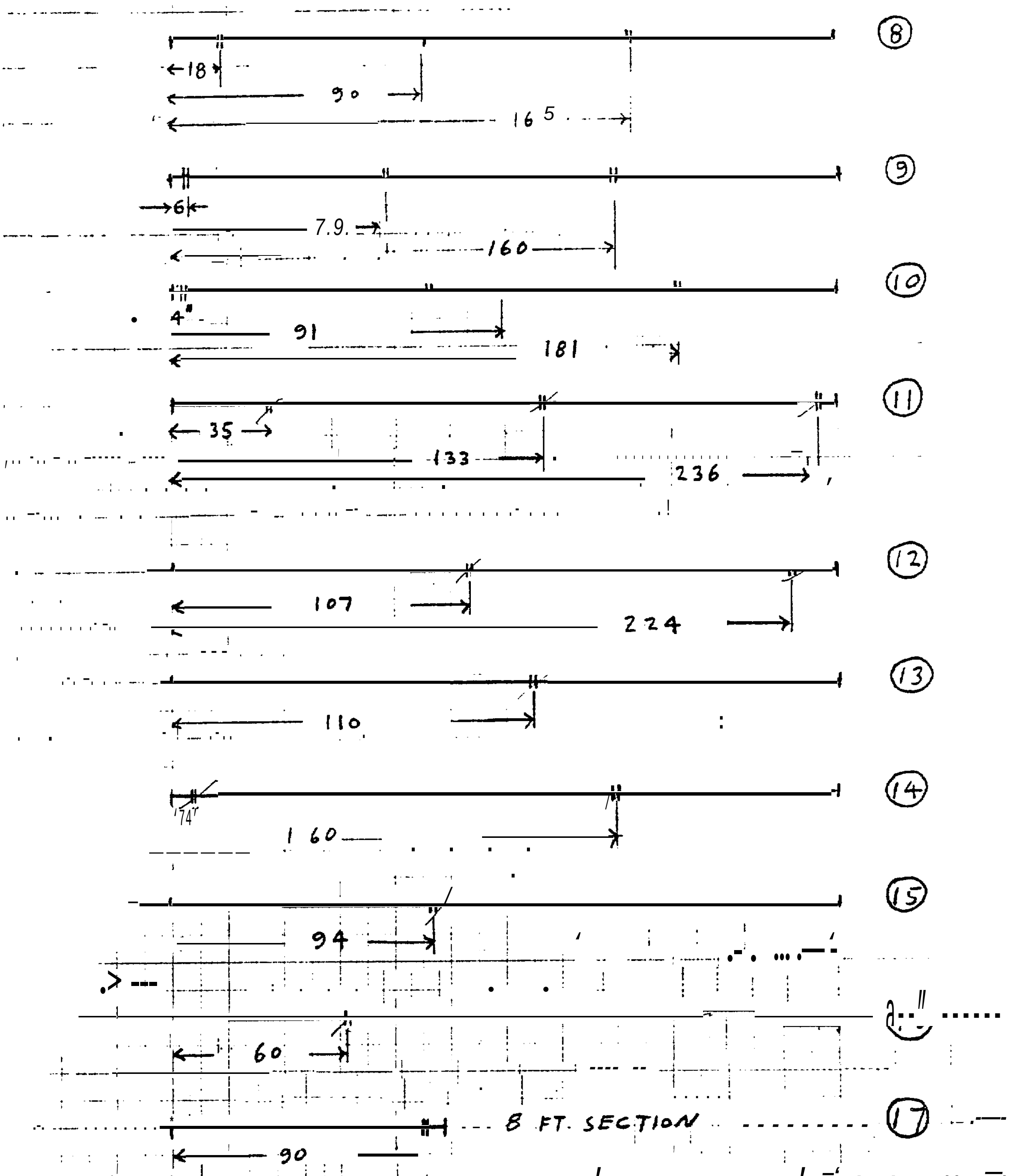
50 Holes to be drilled in line 15/64" DIA
Spacing shown below



SCALE 20 in

ALL DIMENSIONS IN INCHES

OIL DISCHARGE PIPE

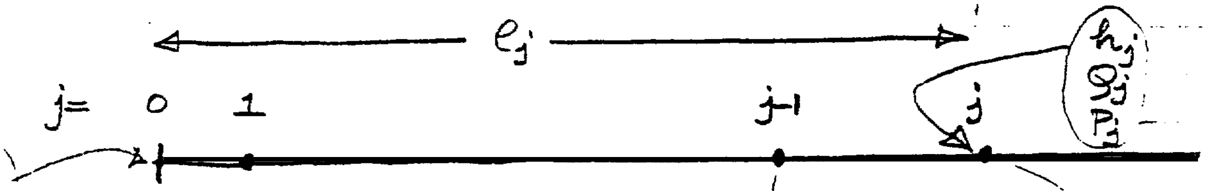


NOTE: ALL PIPE SECTIONS ARE 20 FT. EXCEPT #17

MARK ALL PIPE SECTIONS WITH # AND ARROW → SHOWING FLOW (LEFT TO RIGHT LOOKING AT PIPE AS SHOWN ABOVE

DF Dickins Associates Ltd.

Consider the flow along the pipe.



NOTE: there are two values — one upstream of a hole and one downstream

Given Q_j, ℓ_{j-1}, h_{j-1}, P_{j-1}

$$\Delta P_j = P_j - P_{j-1}$$
$$\Delta \ell_j = \ell_j - \ell_{j-1}$$
$$\Delta h_j = h_j - h_{j-1}$$

$$V_j = \frac{4Q_j}{\pi d^2}$$

$$\ell_j = L\left[\frac{B+h_o}{h_o}\right]\left\{1 - \sqrt{1 - \frac{i}{n}\frac{h_o[2B+h_o]}{[B+h_o]^2}}\right\}$$

$$\Delta \ell_j = \ell_j - \ell_{j-1}$$

$$h_j = \frac{h_o(L-\ell_j)}{L}$$

$$\Delta h_j = h_j - h_{j-1}$$

$$Re_j = \frac{\rho_o d \cdot V_j}{\mu}$$

laminar flow $\quad f_j = 16 / Re_j \qquad Re_j \leqslant 2000$

turbulent flow $\quad f_j = 0.08\, Re_j^{-0.25} \qquad Re_j > 2000$

$$\Delta p_j\,(\text{friction}) = -\frac{2 V_j^2}{d} f_j\, \rho_o\, (\Delta \ell_j)$$

$$\Delta p_j\,(\text{hydrostatic}) = -g(\rho_w - \rho_o)\Delta h_j = -g(\rho_w - \rho_o)(h_j - h_{j-1})$$

$$\Delta p_j = \Delta p_j\,(\text{friction}) + \Delta p_j\,(\text{hydrostatic})$$

$$P_j = P_{j-1} + \Delta p_j \qquad (\text{for the upstream side of hole } j)$$

$$w_j = 0{\cdot}6\sqrt{2P_j/\rho_0}$$

$$q_j = \frac{\pi a^2}{4} w_j$$

$$Q_{j+1} = Q_j - q_j$$

$$V_{j+1} = \frac{4\,Q_{j+1}}{\pi d^2}$$

$$\Delta p_j\,(\text{Bernoulli}) = (\rho_0/2)(V_j - V_{j+1})^2$$

$$P_j = P_j + \Delta P_j \qquad (\text{for the downstream side of the hole})$$

nteresting variables:

$$j \quad \Delta e_j \;,\; e_j \;,\; Re_j \;,\; p_j \;,\; q_j \;,\; Q_j \;,\; \sum_{i=1}^{j} q_i$$

<u>l & Error iteration to the correct solution:</u>

The input flow rate $Q(0)$ is fixed (e.g. $15\,m^3/6$ hours)

d an estimate made for $P(0)$ based on $P(0) \simeq P(\text{average})$

$\sum_{j=1}^{n} P_j/n \;\simeq\; Q(0)/n$ (hopefully). If $\sum_{i=1}^{n} q_i < Q(0)$, increase $P(0)$

rally by $\simeq 2 \times (Q(0) - \Sigma q)/Q(0)$. If $Q_j \leqslant 0$ for any j, merely

guesstimate a decrease for $P(0)$.

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D. F. Dickins

Howard Smith

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Reçu par : ______________________

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FLOW = 552 IGPH

= 11.04 USGPM OIL

PLUS = 55.20 USGPM SEA WATER.

TOTAL = 66.24 USGPM MIXTURE

VISCOSITY = 3.5 CENTIPOISE

$$S.G. = \frac{1}{6} \times .86 + \frac{5}{6} \times 1.03$$

$$= 1.00$$

$\therefore$ VISCOSITY = 3.5 CENTISTOKES

IF WE HAVE 50 HOLES IN SPARGER AND FLOW IS EQUALLY DIVIDED.

FLOW AT SPARGER INLET = 66.24 USGPM

$$v = \frac{Q}{F_1 D^2}$$

$$= \frac{66.24}{352.5 \times (.2417)^2}$$

$$= 3.22 \text{ FT/SEC}$$

$$Re = \frac{F_2 \, v \, D}{\nu}$$

$$= \frac{92937 \times 3.22 \times .2417}{3.5}$$

$$= 20,666$$

FLOW AT LALT HILL $= \dfrac{66.24}{50}$

$$v = \frac{3.22}{50}$$

$$= .06 \text{ FT/SEC}$$

$$Re = \frac{20\ 666}{50}$$

$$= 413$$

FROM "FLOW OF FLUIDS" CRANE TECHNICAL PAPER No 410-C PAGE A-20

ORIFICE DIAMETER $d_o = .25''$

PIPE DIAMETER $d_i = 2.9''$

$$\frac{d_o}{d_i} = 0.09$$

FLOW COEFFICIENT FOR SQUARE EDGED ORIFICE FOR $\frac{d_o}{d_i} = 0$ TO 0.2

Re 2×10^4 $C = 0.595$

Re 413 $C = 0.620$

i.e. C IS ALMOST CONSTANT OVER ENTIRE RANGE.

SUFFICIENT ACCURACY WOULD BE OBTAINED BY ASSUMING $C = 0.600$ OVER ENTIRE RANGE.

AN INCREASE IN VISCOSITY WOULD ONLY AFFECT C AT LOWER END OF SCALE

NOW DISCHARGE THROUGH ORIFICE

$$Q = CA\sqrt{\frac{2g(144)\Delta P}{\rho}}$$

EQN 2-16 CRANE

Q = FT³/SEC

C = .600

$A = \frac{\pi}{4} D_0^2$

g = 32.2 FT/SEC²

ρ = 62.4 LB/FT³

ΔP = P.S.I.

NOW ΔP = INTERNAL PRESSURE (P_i) − EXTERNAL PRESSURE (P_e)

$P_{i_n} = P_{i_{n-1}}$ − ELEVATION HEAD − FRICTION

$= P_{i_{n-1}}$ − CHANGE IN HEIGHT $\times \frac{62.4}{144}$ − FRICTION

$= P_{i_{n-1}}$ − HOLE SPACING $\sin\alpha \times \frac{62.4}{144}$ − FRICTION

$P_{e_n} = P_{e_{n-1}}$ − ELEVATION HEAD

$= P_{e_{n-1}}$ − HOLE SPACING $\sin\alpha \times \frac{62.4}{144} \times 1.03$

$\Delta P_n = P_{i_n} - P_{e_n}$

$= \Delta P_{n-1}$ − HOLE SPACING $\sin\alpha \, \frac{62.4}{144}\left[1 - 1.03\right]$ − FRICTION

$= \Delta P_{n-1}$ + HOLE SPACING $\sin\alpha \left(\frac{62.4}{144} \times 0.03\right)$ − FRICTION

$\therefore$ FOR $\Delta P_n = \Delta P_{n-1}$

FRICTION = HOLE SPACING and $\left(\frac{62.4}{144} \times 0.03\right)$

THIS CAN ONLY OCCUR EXACTLY AT ONE LOCATION BECAUSE FRICTION WILL DECREASE AS n INCREASES.

NOW $q_1 = K_1 \sqrt{\Delta P_1}$

$Q_2 = Q_1 \cdot q_1$

$\text{FRICTION}_2 = f(Q_2)$

$\Delta P_2 = \Delta P_1 + K_2 - f(Q_2)$

NEED TO STORE

ΔP_n

K_1

Q_n,

F_1,

F_2,

F_3,

F_4,

K_2

$$q_{FT^3/SEC} = K' \sqrt{\Delta P_1}$$

$$q_{USGPM} = K' \times 60 \times 7.48052 \sqrt{\Delta P_1}$$

$$K' = CA \sqrt{\frac{2g\,144}{\rho}}$$

$$= 0.6 \times \frac{\pi}{4} D_0^2 \sqrt{\frac{2 \times 32.2 \times 144}{62.4}}$$

$$D_0^2 = \frac{K'}{0.6 \times \frac{\pi}{4} \sqrt{\frac{2 \times 32.2 \times 144}{62.4}}}$$

$$K' = \frac{q_{USGPM}}{60 \times 7.48052 \sqrt{\Delta P_1}}$$

GIVEN DESIRED ΔP 10 TO 15 kPa

$= 1.45$ TO 2.18 psi

SELECT ΔP $= 1.8$ psi

$$K' = \frac{\frac{66.24}{50}}{60 \times 7.48052 \sqrt{1.8}}$$

$$D_0 = .020 \text{ FT}$$

$$d_0 = 0.235 \text{ IN}$$

SELECT $d = 1/4'' = .25''$

$$D_0 = .021 \text{ FT}$$

$$K' = 2.493 \times 10^{-3}$$

$$K_1 = K' \times 60 \times 7.48052$$

$$\boxed{K_1 = 1.1191}$$

$$\therefore q = \frac{66.24}{50}$$

$$\Delta P_1 = \left[\frac{\frac{66.24}{50}}{1.191}\right]^2$$

$$= 1.4 \quad \text{P.S.I.}$$

$$K_2 = \text{HOLE SPACING (FT)} \sin\alpha \left(\frac{62.4}{144} \times 0.03\right)$$

SPACER LENGTH = 100 m = 328.1 FT

No OF HOLES = 50

" " SPACES = 49

$$\therefore \text{HOLE SPACING} = \frac{328.1}{49}$$

$$= 6.70 \text{ FT}$$

$$\text{SLOPE} = \frac{1}{10}$$

$$\alpha = \tan^{-1} .1$$

$$K_2 = 6.70 \sin\left[\tan^{-1} .1\right]\left(\frac{62.4}{144} \times .03\right)$$

$$\boxed{K_2 = 0.008667}$$

FROM "PIPE FLOW 6'"

$$F_1' = F_1 D^2$$

D = PIPE DIAMETER = .2557 FT (3" SCH 40)

$$= 352.51\,(.2557)^2$$

$$\boxed{F_1' = 23.048}$$

$$F_2' = \frac{F_2\,D}{\nu}$$

$$= \frac{92937 \times .2557}{3\text{"s}}$$

$$\boxed{F_2' = 6789.71}$$

$$F_3' = \frac{\varepsilon}{3.7\,D}$$

FOR POLYETHYLENE

ASSUME $\varepsilon = .000\,005$

$\varepsilon/D = 1.9 \times 10^{-5}$

(AT THIS ε AND $Re = 7 \times 10^4$

THIS IS EQUIV. TO SMOOTH PIPE)

(EVEN COMMERCIAL STEEL IS NOT MUCH DIFFERENT FROM SMOOTH PIPE)

$$F_3' = \frac{.000005}{3.7 \times .2557}$$

$$\boxed{F_3' = 5.2849 \times 10^{-6}}$$

$$F_4 = \frac{F_4}{D} \times \frac{L_e}{100}$$

$$L_e = L$$

$$= 6.7$$

$$F_4' = \frac{.67255}{.2557} \times \frac{6.7}{100}$$

$$\boxed{F_4' = 0.1762}$$

Project	By	Date	Page 9 of 25
Subject	Ckd	Date	Job No.

OIL DISCHARGE

FROM INCLINED SPARGER.

R	
0	ΔP_n
1	Q_n
2	K_1
3	K_2
4	F_1'
5	F_2'
6	F_3'
7	F_4'

```
RCL 0
PAUSE        -> ΔPn
√
RCL 2
×
R/S          -> qn
STO - 1
RCL 1
PAUSE        -> Qn
x<0
√
RCL 4
÷
↑
↑
RCL 5
×
PAUSE        -> Re
2
EEX
3
x≥y
GTO 36
7
⇄
÷
.
9
y^x
RCL 6
+
x²
LOG
GTO 40
√
8
÷
÷
x²
RCL 7
×
PAUSE        -> δP_FR
RCL 3
STO - 0
GTO 01
```

$q_n = K_1\sqrt{\Delta P_n}$

$v = \frac{Q}{F_1'}$

$Re = F_2' v$

$Re > 2000$ TURB.

$Re \leq 2000$ LAM.

$-\frac{1}{\sqrt{\xi}} = \log\left[F_3' + \left(\frac{7}{Re}\right)^{.9}\right]^2$ TURB.

$\frac{1}{\sqrt{\xi}} = \frac{\sqrt{Re}}{8}$ LAM.

$\delta P_{FR} = F_4' \left(\frac{v}{1/\sqrt{\xi}}\right)^2$

$\Delta P_n = \Delta P_{n-1} - [\delta P_{FR} - K_Z]$

TEST CASE.

$\Delta P_n = 1.4$ p.s.i

$q_n = 1.32$ USGPM

$Q_1 = 66.24$

$Q_2 = 64.92$ USGPM

$v = 2.82$ FT/SEC.

$R_e = 19,123.56$

$\delta P_{FR} = 0.0366$

$\Delta P_1 = 1.372$

$-\frac{1}{\sqrt{f}}$, $- 6.18$

$f = 0.0262$

$K_1 = 1.1191$

$K_2 = 0.008667$

$F_1' = 23.048$

$F_2' = 6789.71$

$F_3' = 5.2849 \times 10^{-6}$

$F_4' = 0.1762$

$Q = 7.8161$

$Q_2 = 6.492$

$v = 0.282$

$R_e = 1,912.47$

$f = .0335$

$\delta P_{FR} = .0005$

$\Delta P_2 = 1.4082$

TRIAL	ΔP_1
1	1.5
2	2.0
3	1.9
4	1.855

ASSUME $\Delta P_1 = 2.0$ p.s.i

SUPPLY HOSE = 2" DIA

LENGTH = 200 METRES

= 656 FT.

FLOW RATE = 66.24 USGPM

FROM CRANE B-14

60 USGPM IN 2" SCH 40 PIPE $\Delta P_{100} = 2.87$ PSI

FROM GOODYEAR CATALOGUE

60 USGPM IN 2" BORE HOSE $\Delta P_{100} = 3.22$ PSI

∴ 1 FT 2" HOSE IS EQUIV. TO 1.12 FT 2" SCHED PIPE

GIVEN $Q = 66.24$

$\nu = 3.5$ cS.

$L_e = 656 \times 1.12 = 736$ FT

$L/D = 60$

$v = 6.34$ FT/SEC

$Re = 28976$

$\Delta P_{100} = 4.08$ PSI / 100 FT

$\Delta P = 30.41$ P.S.I.

Elevation Head $= -12\ m$

$= -39.37\ ft$

$= -39.37 \times \frac{62.4}{144}$ psi

$= -17.06$ p.s.i.

Head of Seawater $= +39.37$ ft

$= 39.37 \times \frac{62.4}{144} \times 1.03$

$= +17.57$

Pump Discharge Head = Elev Head + Friction Hea[d] + Orifice ΔP + Seawater Hea[d]

$= -17.06 + 30.41 + 2.0 + 17.57$

$= 32.92$ p.s.i.

Say 33 psi.

Seawater Suction Lift.

Flow = 55.20 USGPM

Hose Length = 100 m = 328 ft.

$L_e = 328 \times 1.12 = 370$ ft.

$\partial = \frac{2.1}{1.03} = 2.04$

$v = 5.28$

$Re = 24,147$

$\Delta P_{100} = 2.93$

$\Delta P = 10.83$ p.s.i.

THROTTLE VALVE

CONSIDER 2" GLOBE VALVE $L/D = 340$

AT 55.20 USGPM

$$\Delta P = 1.71 \text{ p.s.i.}$$

NOW $$Q = C_v \sqrt{\frac{\Delta P}{S}}$$

$$C_v = \frac{Q}{\sqrt{\frac{\Delta P}{S}}}$$

$$= \frac{55.20}{\sqrt{\frac{1.71}{1.03}}}$$

$$= 42.84$$

THIS IS CLOSE TO 2" SINGLE PORT FISHER QUICK OPENING.

40% OPEN $C_v = 27.8$

$$\Delta P = \left(\frac{Q}{C_v}\right)^2 \times S$$

$$= \left(\frac{55.20}{27.8}\right)^2 \times 1.03$$

$$= 4.06 \text{ p.s.i.}$$

20% OPEN $C_v = 13.2$

$$\Delta P = \left(\frac{55.20}{13.2}\right)^2 \times 1.03$$

$$= 18.01 \text{ p.s.i.}$$

SW	Project	By	Date	Page 25 of 25
	Subject	Ckd	Date	Job No.

PUMP SUCTION LIFT = 10.83 p.s.i.

PUMP DISCHARGE HEAD = 32.92 p.s.i.

TOTAL = 43.75

THROTTLE VALVE ALLOW ΔP 11.25

TOTAL = 55 p.s.i.

SEA WATER PUMP 55.2 USGPM

AT T.D.H. 55 p.s.i.

<u>OIL PUMP.</u> [illegible]

CONSIDER 2" OIL HOSE

LENGTH = 30 FT.

$\nu = \frac{460}{.86} = 535$ c.s.

$Q = 11.04$ USGPM.

$v = 1.06$ FT/SEC 1.12.

$Re = 31.6$

$\Delta P_{100} = 8.82$ p.s.i.

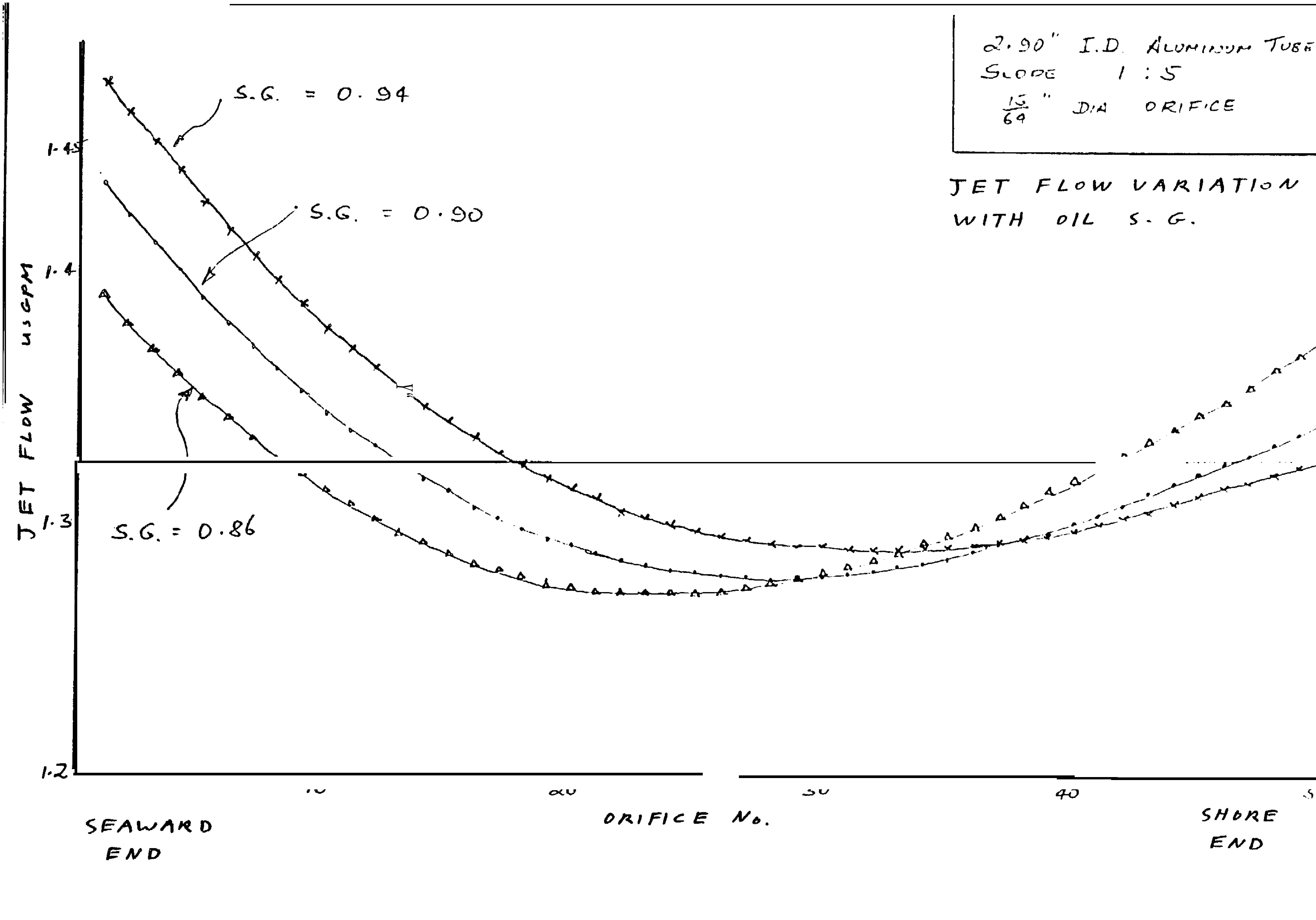
$\Delta P = 2.65$ p.s.i.

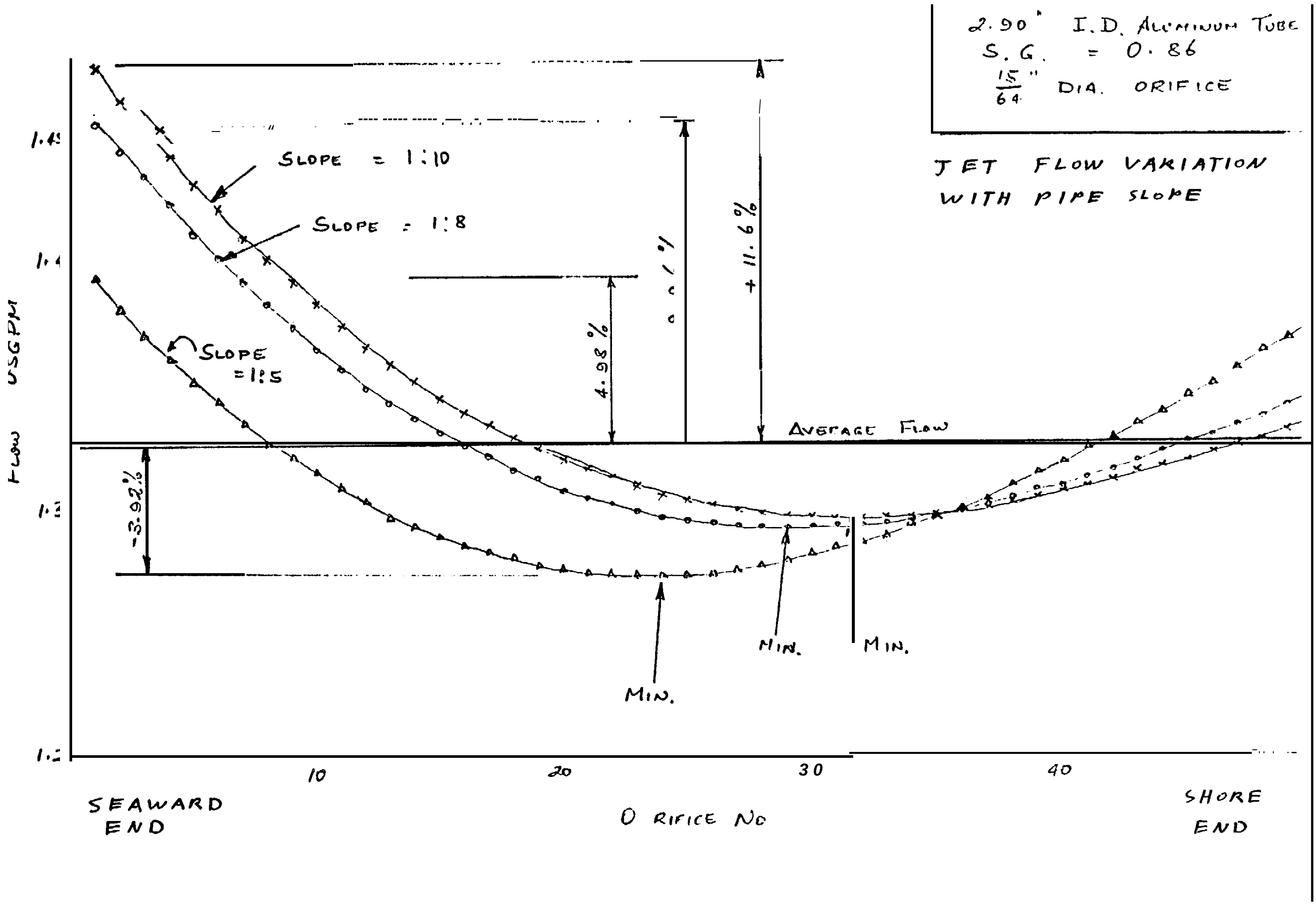
OIL PUMP TOTAL D.H. = 32.92' + 2.65

= 35.57 psi

SELECT MOTOR TO PUMP AT 50 p.s.i.

W | Subject | Ckd | Date | Job No.

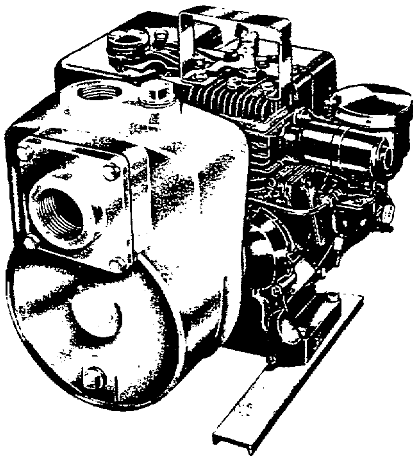




2.90" I.D. ALUMINUM TUBE
S.G. = 0.86
15/64" DIA. ORIFICE
JET FLOW VARIATION WITH PIPE SLOPE
SLOPE = 1:10
SLOPE = 1:8
SLOPE = 1:5
4.98%
+11.6%
-3.92%
AVERAGE FLOW
MIN.
MIN.
MIN.
FLOW USGPM
1.45
1.4
1.3
1.2
10
20
30
40
SEAWARD END
ORIFICE NO
SHORE END

8M

)00 gph 2 inch self-priming
ntrifugal pump. Supplied
th 2.5 horsepower Briggs &
ratton air cooled engine.
ounted on channel base.



SPECIFICATIONS

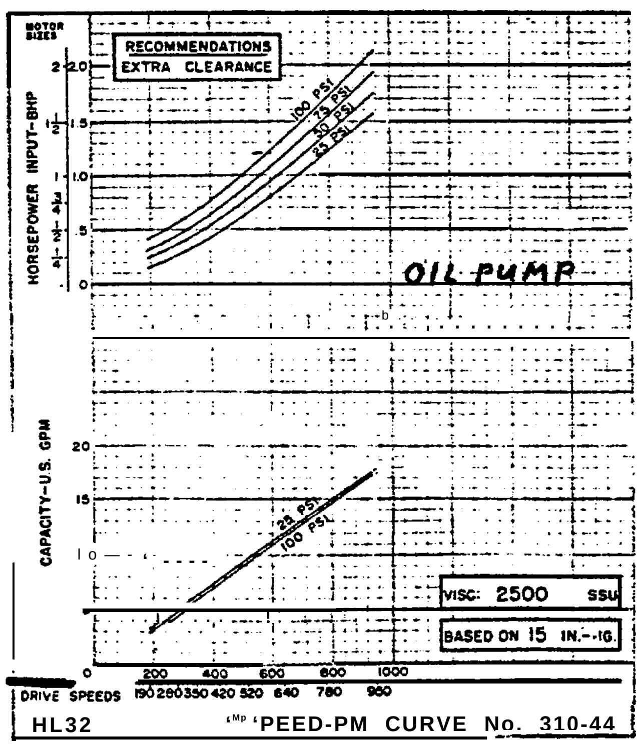
Capacity Rating	Suction and Discharge	Engine Model	HP	RPM	Cubic Inches Displacement	Capacity Gasoline Tank
8,000 G.P.H.	2 in.	Briggs & Stratton 80232	3	3450	7.75	2 Qt.

DIMENSIONS			WEIGHT
Height In.	Width Ins.	Length In.	Net Lb.
14	13¼	17½	60

PERFORMANCE . . .

The following table gives capacity in gallons per minute

Total Head Including Friction	Height of Pump Above Water 5 Ft.	10 Ft.	15 Ft.	20 Ft.	25 Ft.
20	135				
30	125	115			
40	120	115	105		
50	116	104	100	90	
60	106	101	95	87	71
70	95	93	91	81	68
80	81	80	80	71	60
90	60	60	60	60	50
100	28	28	28	28	28
110					



4

Commercial Annubar Flow Calculations

voice	: 74357	05/18/81	
alog Callout	: AWR-71 1" SCH 80		
cessed by	: SM	Annubar Serial Number :	74357.A.1
Information	:		
omer PO No.	: 0028	Calc. Date .	05/18/81
J Type & Name:	Liquid CRUDE OIL	Calc. Number:	74357.A

, Equation Number 1 — Liquid -- Volume Flow

$$= N \times S \times D^2 \times \sqrt{\frac{1}{G_f}}$$

$$Q_A = C' \times \sqrt{h_W}$$

$$h_W = \left(\frac{Q_A}{C'} \right)^2$$

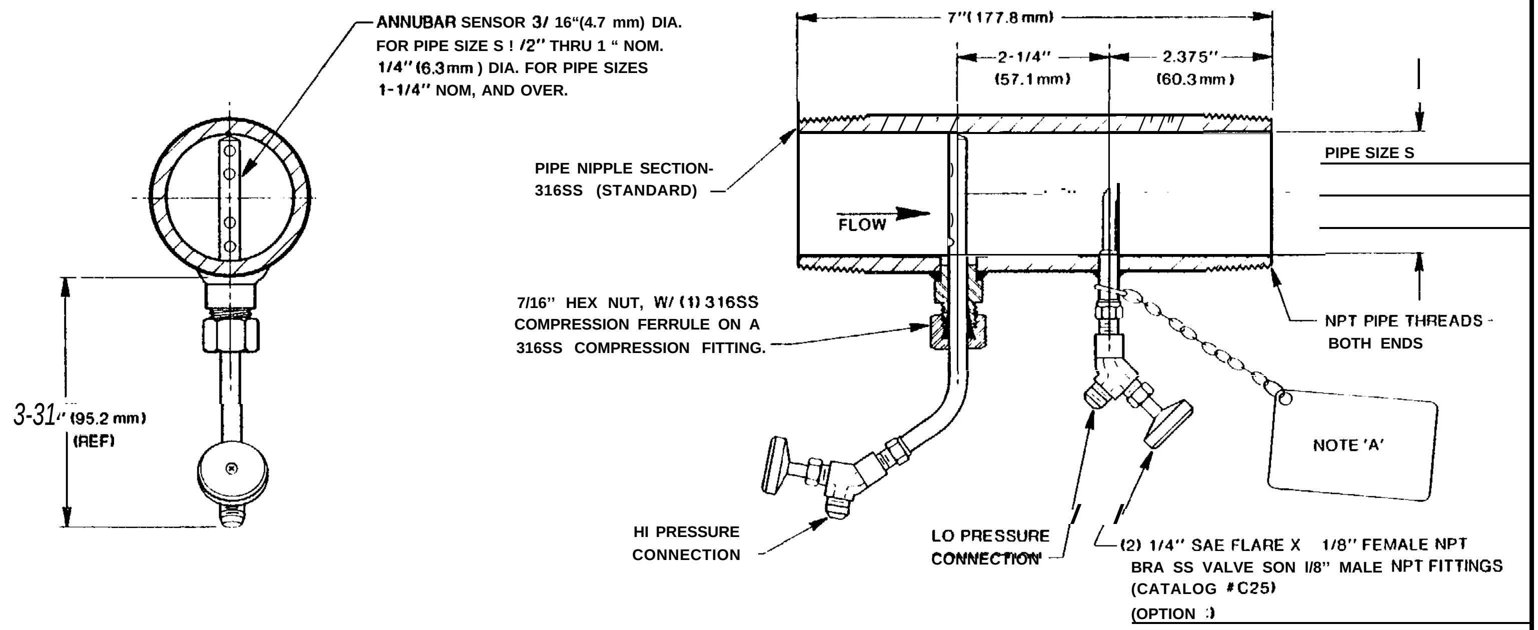
ms Whose **Value is INDEPENDENT of Flow** Conditions:

scription	Term	Value	Units
its Conver. Factor	N	0.0065969	
nubar Flow Coeff.	S	0.6131	
ernal Pipe Diameter	D	24.308	mm

ms Whose Value is DEPENDENT Upon **Flow Conditions:**

scription	Term	Max Flow	Norma 1	Min Flow	Units
OWRATE	Q_A	60	----	----	LPM
LCULATION CONSTANT	C'	2.57746	----	----	
ing Temperature	---	60	----	----	F
owing Pressure	---	60	----	----	PSIG
owing Specific Grav.	G_f	0.860	----	----	
FERENTIAL **PRESSURE**	h_W	542	----	----	mm H20 @20C

Restrictions:			Limiting Component:
lowable Temperature	=	250 F	Annubar Functional Limit
lowable Pressure @ 60F	=	300 PSIG	Annubar Functional Limit
lowable D.P. @ 60F	=	762 mm H20 @20C	
Flow @ Alowable D.P.	=	71.15 LPM	
sonance Flow Range	=	6194 to 9291 LPM	



NOTES

'A'– PERMANENT RUSTPROOF METAL TAG SHOWING MIN., NORM. & MAX. DESIGN FLOWS. METER READINGS FOR DESIGN FLOWS, TAG NO., LINE SIZE. SERIAL NO. 8 METERED FLUID.

PROJECT:

LOCATION:

PIPE SIZE : SCHEDULE :

PIPE I.D. : PIPE O.D. :

OPTIONS- INSTRUMENT FITTINGS:

Dieterich Standard Corporation . Subsidiary of DOVER Corporation

Box 9000 • Boulder, Colorado 80306 USA

ANNUBAR MODEL AWR-71

APPROVAL		LATEST REVISION	
By C. Britton	Date 7/31/79	Letter	Date
Drawn by DCW	Checked by Hilda Tuth	Date Drawn 30 JULY 79	Scale N.T.S.

C-9900

Commercial Annubar Flow Calculations

oice : 74357 05/18/81 WESCAN SYSTEMS
alog Callout : AWR-73 2" SCH 40
cessed by : SM Annubar Serial Number : 74357.B.1
Information :
'omer PO No. : 0028 Calc. Date : 05/18/81
j Type & Name: Liquid SALT WATER Calc. Number: 74357.B

. Equation Number 1 Liquid -- Volume Flow

$$= N \times S \times D^2 \times \sqrt{\frac{1}{G_f}} \qquad Q_A = C' \times \sqrt{h_w} \qquad h_w = \left(\frac{Q_A}{C'} \right)^2$$

ms Whose Value is INDEPENDENT of Flow Conditions:

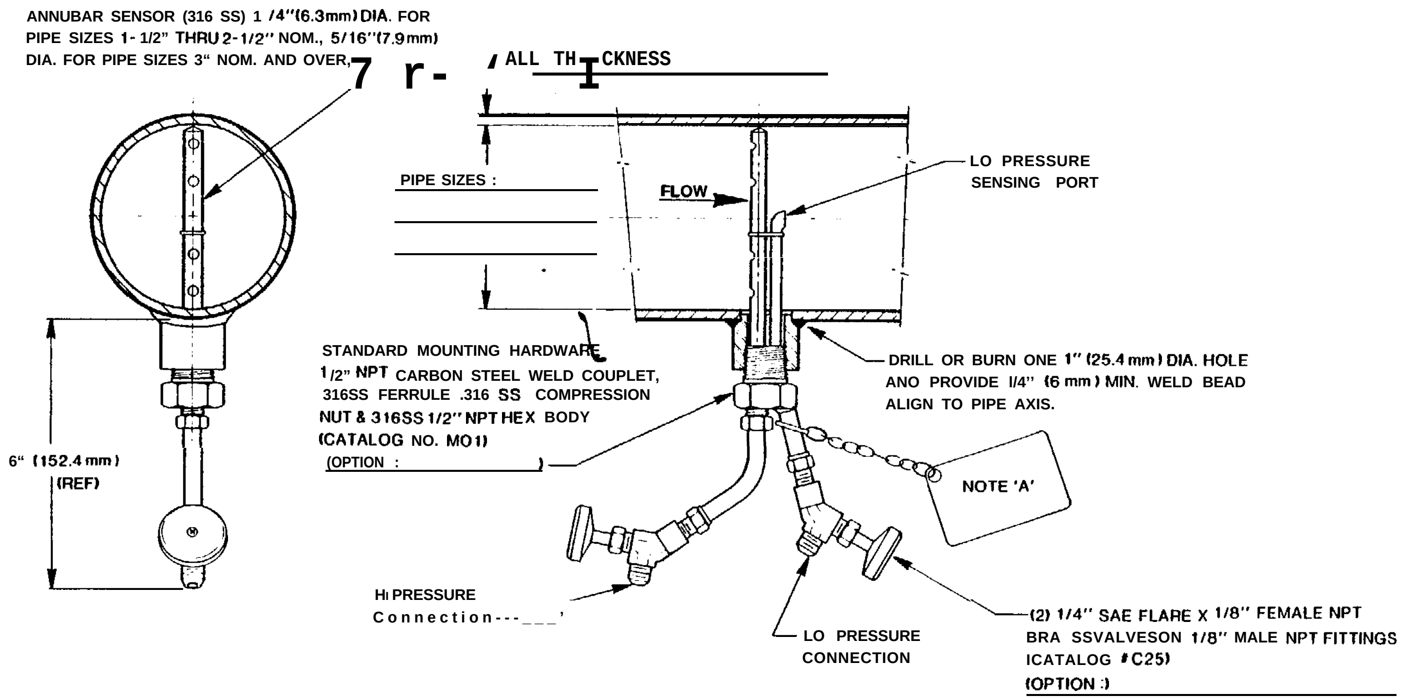
cription	Term	Value	Units
ts Conver. Factor	N	0.0065969	
ubar F1ouJ Coeff.	S	0.7095	
ernal Pipe Diameter	D	52.502	mm

ms Whose Value is DEPENDENT Upon Flow Conditions:

cription	Term	Max Flow	Norma1	Min Flow	Units
WRATE	Q_A	250	----	----	LPM
CULATION CONSTANT	C '	12.7114	----	----	
ing Temperature	---	32	----	----	F
wing Pressure	---	70	-- --	----	PSIG
wing Specific Grav.	G_f	1.030	----	----	
FERENTIAL PRESSURE	h_w	387	----	----	mm H20 @20C

Restrictions: Limiting Component:

owable Temperature = 250 F Annubar Functional Limit
owable Pressure @ 32F = 300 PSIG Annubar Functional Limit
owable D.P. @ 32F = 762 mm H20 @20C
Flow @ Alowable D.P. = 350.9 LPM
onance Flow Range = 9919 to 14880 LPM



NOTES

"A"-PERMANENT RUSTPROOF METAL TAG SHOWING MIN., NORM. & MAX. DESIGN FLOWS, METER READINGS FOR DESIGN FLOWS, TAG NO., LINE SIZE, SERIAL NO. & METERED FLUID,

PROJECT :

LOCATION:

PIPE SIZE : SCHEDULE :

PIPE I.D. : PIPE O.D. :

OPTIONS- MOUNTING HARDWARE:

INSTRUMENT FITTINGS :

NOTES :

Dieterich Standard Corporation . Subsidiary of DOVER Corporation

Box 9000 • Boulder, Colorado 80306 USA

ANNUBAR MODEL AWR-73

APPROVAL		LATEST REVISION		
By: T. Britton	Date: 7/31/79	Letter	Date	
Drawn by: OCats	Checked by: Hilda Tirth	Date Drawn: 30 JULY 79	Scale: N.T.S	C-9910

Note: Optional **saddle** mount drawing for AWR 73, C-9940, is available **upon request.**